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OPERATIONS RESEARCH AND ECONOMIC ANALYSIS SYMPOSIUM PROCEEDINGS--ETC(U)
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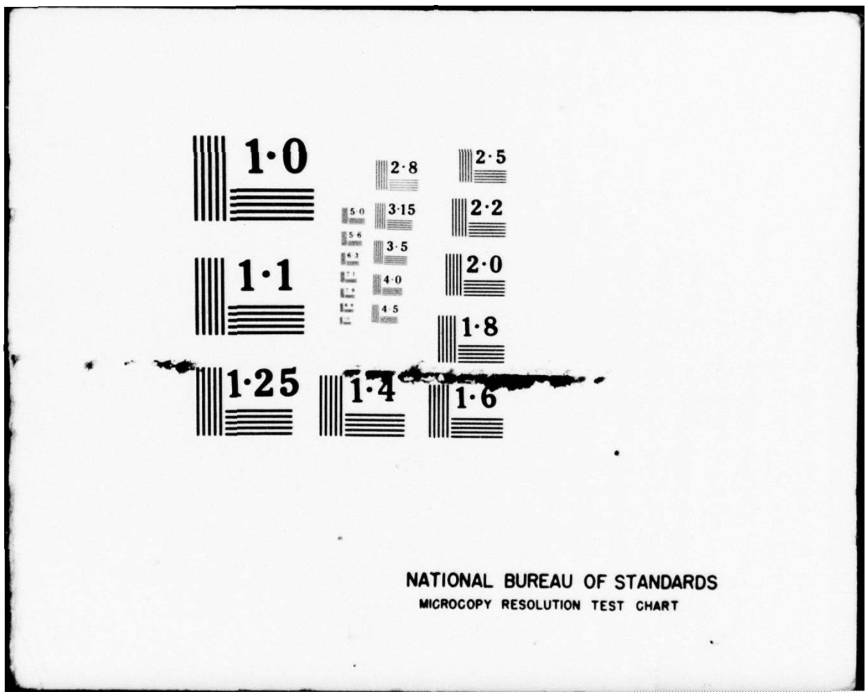
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DEPARTMENT OF DEFENSE

DEFENSE LOGISTICS AGENCY

Cameron Station,
Alexandria, Virginia 22314

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DEFENSE LOGISTICS AGENCY
HEADQUARTERS
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

DLA-LO

29 July 1977

FOREWORD

The Defense Logistics Agency Operations Research/Economic Analysis Symposium was held 12-13 July 1977. It provided the opportunity for all concerned DLA personnel to meet and discuss the various actions being taken throughout the command with respect to operations research and economic analysis. The purpose of the Symposium was to promote an interchange of ideas and technical information between field and Headquarters representatives in order to obtain more effective use of these techniques in DLA.

Enclosed are submissions for all presentations. Where actual papers were not submitted, summaries of the presentations are provided. A list of contributors and their phone numbers, along with a list of all attendees, are also furnished.

Eugene B. Sterling
EUGENE B. STERLING
Major General, USAF
Assistant Director
Plans, Programs and Systems

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OR/EA SYMPOSIUM WELCOMING SPEECH
by
GENERAL STERLING

General Sterling began his welcoming address, by stating that he considers OR/EA to be one of the important functions for DLA planning. More and more the Government Accounting Office (GAO), DOD and Congress raise questions concerning our need for particular systems or projects. We must be able to show that we have performed objective, logical economic analyses and have considered all of the alternatives. He stated that DLA must rely to an even greater extent than before upon logical scientific management techniques; adding that OR/EA staffs in DLA may be small, but they are well qualified, and management should make good use of them.

In the future, there should be greater sharing of the overall DLA scientific talent. Studies performed at the Headquarters affect field activities, just as studies performed in the field affect the Headquarters. Joint participation is essential to good results. The Headquarters OR/EA staff will be relying to a greater extent upon the OR talent in the field. When a study is required at DLA, it should be developed and planned by the Headquarters OR/EA Office and, where appropriate, farmed out to those OR people who are close to the problem and the data. Then their results should be collated at the Headquarters and an overall DLA report published. In this manner, we can make even better use of the scarce OR talent.

A few of our unsolved issues and problems in logistics are:

Supply Management. About 50% of the Defense Logistics Agency's mission is supply. Although we have done quite well in this area, we can continue to improve our materiel distribution system. The JLC Department of Defense Materiel Distribution Study Group is presently conducting an in-depth study of all DOD depots. When the results are published, it will fall upon the operations research analysts to help management review and understand what has been done.

Procurement Management. The procurement people and the supply people have many common interests. EOQ, phased deliveries, small business and lead times offer areas for furthur study.

Transportation is interwoven closely with Supply Distribution and Procurement Management. Transportation is the largest time segment in the pipeline and in DLA there is a variety of transportation problems such as surface shipments, air shipments, DICOMSS, DPDO, and the Intransit Visibility Systems.

Facilities Management. There have been several studies going on in these areas; the DESC Depot Mission, the DPDOs, the DCASRs; DODMDS is looking at all the depots and in the normal course of events, DLA shall be examining the ICPs.

In relation to facilities management, the area of Bureau of the Budget Circular A-76 needs to be addressed. More economic analyses need to be conducted to assist in decisions of contracting out versus doing things in-house.

Manpower Planning is an area of research for forecast of manpower and training requirements. The Executive Director for QA has stated the first DLA effort in this area, and the Headquarters OR shop is developing a model for Quality Assurance personnel. There are undoubtedly other applications.

ADPE. And not the least concern is phenominal growth of computer applications.

General Sterling's concluding remark was that the OR/EA analysts. by working as a team, can become one of the most influential factors in the planning and management of the Denfense Logistics Agency.

CURRENT TRENDS IN ECONOMIC ANALYSES

by Louis Zamarra

INTRODUCTION

This morning I would like to discuss economic analysis in DLA:

1. The type of economic analyses we perform in Headquarters and how we otherwise keep busy,

2. Introduce you to those who do these analyses, and

3. Discuss some current trends in economic analyses.

ECONOMIC ANALYSIS DEFINED

For those in the audience not acquainted with economic analysis, let's define it. Economic analysis is nothing mysterious or exotic. It is nothing more than a systematic way of examining problems which involve the expenditure of funds. The three major steps in the process are:

1. Define what needs to be done - determine the objective.

2. Identify alternative ways of accomplishing what needs to be done. There are almost always alternatives; one alternative frequently being not to do anything.

3. Costing those alternatives in terms of one-time and recurring costs.

Economic analysis is intended as an aid to the decision-maker by showing him the economics or costs of each alternative. Economic analysis does not make decisions; management makes decisions. Certainly, management is in a much better position to make decisions when it knows the economic consequences of the proposal. But management must also weigh the noneconomic factors which the analyst may not have considered, such as the environmental consequences, the political consequences, and the fact that there may be other, more pressing needs, for the limited resources at its disposal.

Our job is to either perform economic analyses when asked or to encourage the proponent to perform the economic analysis himself. The proponent is usually in a much better position to fully assess the benefits of his proposal. We provide assistance as required. We've found that economic analysis is also a useful planning tool in that it forces one to think through his problem and look downstream as to the full consequences of the proposal. A further benefit of performing an

economic analysis and having it documented is that it can then serve as a benchmark to determine how well we estimated the costs and if, in fact, the projected savings were realized.

PAST PROJECTS

Most of the economic analyses that we have performed relate to automatic data processing projects. Our Agency spends about 10% of its annual budget in ADP and most new proposals are reviewed at the OSD level. Fortunately, the OSD Comptroller who reviews ADP projects always asks if an EA has been performed. We have also worked on some consolidation projects, MILCON projects, and some projects on behalf of OSD.

Last year we published a Compendium of projects completed by our Office. Most of those projects that we've worked on are abstracted therein. Copies of the Compendium were forwarded to all field activities and headquarters staff elements. If anyone wishes a copy, we still have a few left.

We plan to update the Compendium later this year. If anyone has a completed OR/EA study and would like to have it included, please send it to our Office, DLA-LO. We are particularly interested if the results or the methodology may be useful to others.

CURRENT PROJECTS

Some of the projects we are working on now include: an evaluation of a Technical Information Storage and Control System - this is a proposed computerized system which provides a cross-reference of DoD drawings and part numbers and automatically generates external data requests to the Military Services repositories and industry. Another project involves statistical assistance to DIPEC in analyzing a government visibility system for Other Plant Equipment in the hands of contractors, as opposed to Industrial Plant Equipment. Another project is the determination of a proper overhead charge to be allocated to various economic studies. A fourth project is the preparation of an economic analysis manual which will serve as a cookbook and show, in easy to understand fashion, how to perform your own economic analyses. We hope to have the manual completed before summer is out and will make wide distribution of it throughout the Agency.

THE EA BRANCH

Now I would like to introduce the people who are working on these projects. I have a B.S. degree in Engineering from Newark College of Engineering and an MBA from Auburn. My colleagues are: David Polinsky who has a B.A. in Math from Brooklyn College, Dick Brown who has a B.S. in Math from Maryland University and is currently working on an MBA at American University; and Denise Wieczorkowski who has a B.A. in Economics from Indiana University of Pennsylvania and an M.A. in Economics from George Mason University.

CURRENT TRENDS ECONOMIC ANALYSES

OMB CIRCULAR A-76. This is an instruction issued by the Office of Management and Budget which prescribes, amongst other things, how analyses are to be performed which compare contracting out versus doing the work in-house. Prior to last fall, 9% was prescribed as an add-on factor to represent the government's contribution to employee benefits. Last fall, the Ford Administration issued a change to A-76 which indicated the rate to be used should be 28%. The Carter Administration has recently changed the rate to 18%. OMB is currently studying the problem and should finish its deliberation before summer is out. We have provided some input, indicating that there should be consistency in the analysis methodology prescribed by the various OMB circulars. As some of you may know, our Economic Analysis Regulation, DLAR 7041.1, derives from OMB Circular A-94 which differs considerably from A-76. We have pointed out some of the inconsistencies, and hopefully some changes will be made.

The implications of the higher add-on rates for government benefits bode ill for labor-intensive functions for two reasons. First, it will push more work into the private sector when comparing in-house versus contracting out projects. Secondly, it will make more automation of manual operations profitable. Dick Brown will have more to say on this subject tomorrow morning.

MILCON. Another area which will see increased use made of economic analysis is in the justification of Military Construction projects. All Military Services were recently criticized by GAO in their failure to perform adequate economic analyses for MILCON projects. Two years ago, in DLA, we instituted a procedure for evaluating MILCON requests which gave considerable weight to those which were economically justifiable. Those projects which had no economic justification usually ended up at the bottom of the shopping list.

We have recently asked our Installation Services Directorate to change their MILCON regulation to specify in the justification that an EA has been performed or, if not, why not.

DIFFERENTIAL COSTS. A third area of current interest in economic analysis can be covered under the general umbrella of differential costs. By this I mean that there will be some changes made in the way we treat certain costs in future economic analysis. The emphasis will be on examining future cost differentials when examining alternatives as opposed to our past emphasis of examining total costs. In this context, our project on determining overhead costs which I mentioned earlier, may have limited value. An allocation of overhead costs, in our current thinking, will be unnecessary unless the overhead will in fact change by adoption of a certain alternative. I think this is consistent with the concept of sunk costs.

Under the sunk cost concept, we downplay costs already expended. While they may be nice to know, sunk costs are eliminated in examining alternatives. The idea being that it should not influence the decision; it's unwise to throw good money after bad.

OPPORTUNITY COSTS. Another important area deserving mention is the explicit identification and inclusion of opportunity costs when comparing alternatives, particularly if there is an alternative use for the resources. When considering personnel resources, we always assume that the personnel would otherwise be gainfully employed. The explicit identification of opportunity costs will also make the economic analysis a more useful tool for the budgeteers; they are more interested in the addition or deletion of resources which the adopted alternative dictates. Identifying the opportunity costs, simplifies the procedure.

CONSERVATISM. A final point I would like to make is that in future economic analyses, we will stress the principle of conservatism. By this I mean that when there is uncertainty about costs, they should be overstated, particularly as the costs pertain to the preferred alternative. Likewise, if there is uncertainty about benefits or savings, these should be understated. If the project is still worthwhile, it will in all probability be approved.

SUMMARY

Most of these points should be adequately covered in the Economic Analysis Manual which, as mentioned earlier, will be distributed later this summer.

To sum up, look for increased usage of economic analyses, particularly with respect to Military Construction Projects. Also look for consistency of approach to various type economic analysis, a higher rate than 9% for government benefits, increased attention to differential costs, explicit identification of opportunity costs, and a conservative approach in undertaking economic analyses.

PITFALLS, PRATFALLS AND PRACTICAL APPLICATIONS OF OPERATIONS RESEARCH

by
Laurence G. Kohler

My concept of what this Symposium is all about is to enhance the quality of management decision-making in DLA through the use of operations research and economic analysis.

I came across these words describing OR in another meeting I recently attended.

> "The characteristics of this profession are the difference between its literature and its practice, and the strength of the faith of some of its practitioners. It possesses idols and prophets, and strong expansionist tendencies, linked to an attempt to patent the intellectual virtues. Its practitioners have been described as physicists now rediscovering elementary economics. Current tendencies include a demand for salesmanship and efficient rhetoric from its neophytes."

Though these words are obviously facetious you will note some element of truth in them. That is why I have titled my remarks Pitfalls and Pratfalls as well as Practical Applications. OR can be a powerful aid to decision-makers - but only if it is properly applied. Applied erroneously, it can be disastrous.

To talk about OR we need a common understanding of what it is. Those of us who are practitioners should know what it is. For those that are managers; hopefully we've done something for you sometime which has given you at least a hint of what OR is all about. Just for the record, however, I'll read the definition of OR found in our own DLA Reg. 5100.3:

> "OR and EA refers to quantitative analysis of a problem and alternative solutions thereto, commonly referred to as 'advanced (scientific) aids for decision making' and encompassing the techniques of management science, operations analysis, systems analysis, decision theory, probability statistics, cybernetics, mathematical programming, queuing theory, game theory, inventory theory, and simulation..."

To me the operative words in that definition are: quantitative; problem; and solutions. As the rest of the definition implies, OR is definitely

the application of quantitative techniques to the solution of problems. And this is the point I want to emphasize to the practitioner: OR is the solution of real problems, not the application of a pet theory or technique. The use of mathematical theory and tools is justified only to the extent that it yields improved solutions to real problems. As long as over-all economics is a criterion, the cost of using sophisticated tools is as real as any other cost and must be considered in appraising the merits of such tools. More about that in Pitfalls and Pratfalls. First, I want to talk about the good news: Practical applications:

Most of you who have made OR studies or have had the benefit of an OR study of some problem are well aware that a key concept of OR is the use of mathematical models; simulation models; transportation models; linear programming models; analytical models; etc. The goal of decision-making is to arrive at a decision and implement it in the real world. What lies in between is a process of mapping the real world into a simplified model (conceptualization) and deriving a solution from it. It is this simplification process that is both the strength and weakness of OR.

PRACTICAL APPLICATIONS

Some practical examples of how OR, through the use of simplified models, has and can help the DLA manager are:

1. Economic Order Quantities (EOQ) - Compares the cost of buying an item with the cost to hold the item to determine how often and how much to buy. Another factor now being considered for inclusion in DLA's EOQ model is the discount offered by many vendors for buying large quantities of an item.

2. Safety Levels (VSL) - This model determines how much safety level to hold for each item in order to minimize the average time items are on backorder given a certain investment in safety level stock.

3. Economic Retention - This model determines how much stock on hand should be retained. The model uses the cost of procurement, storage and disposal and the probability of future demands for an item to compute retention levels.

4. Item Stockage - This model determines whether it is economic to stock an item which is centrally managed by DLA. DoDI 4140.42 prescribes the model to be used for initial provisioning items. A similar model for items already in the system has been developed and is still being evaluated. The delay in implementation is not due to deficiencies in the model but rather in the values assigned to the elements in the model, a problem I'll discuss under Pitfalls.

5. Distribution Patterns - Those of you in the distribution end of the business are familiar with the use of transportation models to

determine where to position our stock. These models use inbound and outbound transportation costs to determine ideal stock locations within the DLA depot system. You may be aware of the DoDMDS study which is attempting to use a transportation model, with some other esoteric techniques to determine an optimum DoD distribution system.

6. DICOMSS - This model attempted to simulate the DICOMSS operation at DDMP in order to evaluate alternative ways of performing that operation.

7. Tanker Scheduling - This model determines the scheduling of ocean-going tankers supplying petroleum products so as to minimize the total cost. A more sophisticated modelling of the fuels distribution system is now underway in DFSC. It will cover all facets of fuels distribution.

8. Stock Availability vs. Resources - The USIMS, a model of SAMMS, was used to develop a methodology for minimizing degradation of stock availability if funds are reduced or conversely, of minimizing the investment in stock funds and operating costs to achieve higher availability goals. This project illustrates the versatility of usefulness of the USIMS as a tool available to all Supply Center managers.

9. Manpower Planning - This model will forecast the number of new Quality Assurance personnel needed in the future to replace current personnel who leave the Quality Assurance field for one reason or another. If successful, this model has great potential for application in other fields.

These examples illustrate some of the kinds of challenges which have been or are being tackled by OR. You can see from these examples the diversity of OR application.

A couple of problems which are potentially soluble by OR were surfaced at last week's Monthly Management Review: (1) The old bugaboo of customer returns - we need a criterion for determining how much and when to accept returns; (2) Efficiency vs. Effectiveness - how can we usefully relate productivity to the quality of our product or service.

PITFALLS

Now that I've illustrated the usefulness of OR in helping managers make better decisions, I want to point out some limitations or pitfalls to watch out for.

1. Being a slave to a technique - there are many quantitative techniques available to the operations researcher which are very powerful when properly applied. Some of these, such as simulation or regression analysis are very flexible and are used as readily as algebra by our analysts. Others, like queuing theory or special algorithms for transportation or assignment problems are more esoteric and we don't find much real world application, even though we'd love to try them. The pitfall

that we practitioners must look out for is that we don't distort the "real" world in trying to make our problems fit the available techniques, whether the technique is simple or sophisticated. The most recent example I can think of is the use of mathematical programming to solve a stock assignment problem. This would appear to be a classic problem which has been addressed thousands of times in classrooms and textbooks. However, those solutions always seem to come pre-packaged with all the necessary data, a condition we don't seem to find in the real world. In this case a modified approach to solving the problem had to be taken using a combination of math programming, plain old algebra and common sense.

My point is don't oversimplify in attempting to model the real world, just so the solution can be reached using a particular technique.

A pitfall also exists for the manager regarding oversimplification. I know its faster, cheaper and easier to reduce our decision rules to one, two or three numbers. I have no argument with that, when it does not affect the quality or economics of the decision. But often we are dealing with complex problems which cover many different circumstances. To replace an OR developed formula which accounts for these diversities, with a one or two number threshold sometimes produces bizarre results. Just because we can't always give you neat threshold values, don't throw the product away. Let us test the results of our formula against your thresholds to see if it makes any difference in the outcome. Complexity for complexity's sake is not our bag.

2. Data - There are several pitfalls regarding data which we must be wary of:

a. When it doesn't exist - the danger here is to assume data that don't exist rather than collect accurate data. We usually fall into this trap when we are pressured for a quick answer. To the practitioner I say: if you must assume, test your outcome through sensitivity or risk analysis; to the manager I say: if you want a quick answer and data aren't available, be careful how you use the result. We have experienced several cases recently where historical data are not available. One of the projects in the mill is to develop an adequate data base.

b. Imprecise data - the danger here is in producing precise answers from imprecise data. The nature of many OR techniques causes them to produce very precise answers which then become fact. Often these answers come from initial data which is very imprecise (estimates or averages). OR models are somewhat like computers - they operate under the GIGO principle. But I'm not talking about garbage, but rather good data interpreted improperly.

3. Biting off more than we can chew - the problem here is somewhat like some of our data systems - we try to squeeze the whole world and all its problems in a single model. We usually wind up with a much smaller product which took two or three times as long to develop than if we had

set our sights lower to begin with. The recent RIMSTOP simulation is a good case in point. We wound up with an excellent product but it was much smaller in scope than originally envisioned and took a year longer than planned to complete.

This list of pitfalls is by no means exhaustive but I think I've covered the major ones.

PRATFALLS

Webster defines a Pratfall as a fall on the buttocks. We've experienced a few of those in the application of OR. Usually because we've fallen into one of the previously described pits. A couple of examples will reinforce the point I want to make about being wary.

1. We once applied the travelling salesman algorithm to a problem involving the routing of customer assistance reps. This is a perfectly good technique and we did reach a solution for the initial phases of the problem. The only trouble was that it cost more to run the computer program than could be saved in scheduling by the algorithm. Remember what I said earlier about the economics of OR and being slaves to techniques?

2. Another case involved the attempted use of queuing theory to solve a problem relating to Procurement Administrative Leadtime (PALT). After six months we found out that the queuing math wasn't developed enough to handle the problem. We resorted to simulation for a solution. Remember what I said about textbook problems being neatly pre-packaged?

I don't want to belabor our shortcomings any more, but I think you get the point I'm trying to make, so I'll close by summarizing.

SUMMARY

I've illustrated how OR has been and can be a useful tool for helping managers make better decisions. In the interests of the objectives of this symposium I've pointed out some pitfalls to look out for in applying OR. Many of the applications I've mentioned will be discussed in this symposium. I hope my remarks will help to make those discussions more fruitful.

Dr. Jacob Stockfisch's Address on
THE INVESTMENT COST OF LOW DEMAND ITEMS
by Denise Wieczorkowski

INTRODUCTION

Dr. Stockfisch was invited to address the interest cost of holding inventory for low demand items. A brief background to the problem will be given, followed by the specific question proposed to Dr. Stockfisch and a summary of his response.

BACKGROUND

The general view taken towards the investment of funds in inventory is that each public dollar so invested represents a dollar of investment in the private sector foregone. In accordance with DoD 4140.39, "Procurement Cycles and Safety Levels of Supply Secondary Items," July 17, 1970, an annual investment charge of 10% of the average inventory on hand is made in determining how much stock to buy and hold.

Because of changing demands, many items in the military inventory are held for many years longer than originally anticipated. The determination of whether or not and how much of this stock to hold is an economic problem involving the probability of demand, future availability, military criticality, cost to repurchase and cost to hold. Because of obsolescence or their uniqueness to military use, many of these items have little or no value in the private sector. In the past, the economic decision to hold this stock has included an investment charge of 10% on the value of inventory held.

PROPOSED QUESTION

The proposed question was essentially twofold:

1. If the government continues to hold these items, should an investment cost be charged? Is the 10% rate currently prescribed appropriate? If so, what is the significance and origin of the 10% figure? If not, what rate is correct, and what is the rationale for using it?

2. Whatever the appropriate rate is, to what valuation of inventory stock should it be applied: the original acquisition cost of the stock, its current replacement value, the revenue it would bring through surplus sales, or other? Why?

RESPONSE

In answer to the question, Dr. Stockfisch stated that an investment cost should indeed be charged to the low demand items currently held in military inventories. The cost should be in the form of an interest rate

applied to average on hand inventory. When the government invests in inventory, it displaces real physical resources. It is the productivity of those resources which is surrendered as a result of the government investment. Thus, the rate should be a uniform rate for all items held in stock. Whether a particular item is fast moving or slow moving has no effect on the appropriate rate to apply.

Although Dr. Stockfisch considered the current 10% rate to be an appropriate rate, he stated that an updated study of the economy would probably reveal a rate slightly lower. The 10% rate represents an estimate of the average rate of return or rate of profitability obtainable from investment in the private sector of the American economy before corporate taxes and after adjusting for inflation.

In answer to the second part of the question, he stated that in all cases the investment cost should be applied to the current value of the inventory, i.e., the value it could bring in today's market. For fast moving items, this value will generally be the original acquisition cost. For those items having little or no demand this value is the amount that could actually be obtained through its sale. In some cases this value may be negligible.

PRIORITIZING MILCON

by George Funk

1. Our presentation this afternoon concerns the Prioritizing Military Construction projects through the use of economic analysis.

To give you some background into the concept we'll be presenting, I would first like to familiarize you with the mission and organization structure of the Defense Property Disposal Service.

2. The Defense Property Disposal Service (DPDS) is responsible for disposing of excess personal property generated by the military services as well as other DoD agencies. Disposal may entail reutilization of the property within DoD, transfer to other Federal government, sale to the public, or abandonment or destruction.

3. To accomplish this mission, DPDS has a world wide organization consisting of 259 field activities. 154 of these activities are either Property Disposal Offices (DPDO) or Holding Activities consisting of facilities for receiving and storing usable property and scrap, secure areas for storing pilferable property, and areas for administrative and sales purposes.

4. It is these Property Disposal Offices and Holding Activities, colocated at host installations, which created the problem of Prioritizing Military Construction projects.

5. Systems for Prioritizing MILCON projects have existed within DPDS which take into consideration workload and past profitability of a DPDO, as well as subjective factors relating to safety and morale. Various systems were used by different regions. The construction projects would be prioritized by the regions and forwarded to HQ DPDS where they were reprioritized for submission to HQ DLA.

6. This is a system which was tried and rejected. It was based on workload and profitability. The larger the workload and higher the profitability, the higher the priority of the project. Even though the cost of the MILCON is listed, it was not taken into consideration in setting priorities.

7. On this slide and the next slide, we have a priority system which included such factors as the level of the direction that initiated the MILCON request, deferrability (based on whether the project is considered essential or just desirable).

8. And impact on safety, security, morale and welfare.

9. This system was used to set priorities based on the type of facility the request encompasses. Using this system, requests for scrap bins . . . would rank higher than requests for roads and parking lots . . .

10. It was felt that the systems being used were too arbitrary for making decisions involving the expenditure of several million dollars. We, therefore, decided to attempt the development of a priority system based entirely on economic factors.

Above paragraph numbers refer to charts which follow.

11. In developing the system we determined that there was a need for more comprehensive data and quantification of relevant factors using dollars as a common denominator. To accomplish this we proposed a system whereby the DPDO Chief would supply all required justification for the requested project. Expressed in dollars. The data would be validated by the region facilities engineer and forwarded to HQ DPDS to be centrally prioritized to reflect total DPDS requirements. Our objective is to give the highest priority to proposed MILCON projects which will maximize dollar return, minimize expenses, and therefore provide us with the best net annual benefit for the money expended.

Naturally prior to approval of MILCON requests, other alternatives such as minor construction, cube storage, and improved layouts will be considered. If it is determined that one of these alternatives is less expensive, it would be pursued.

12. These are the factors which were considered in the development of this system. (Most DLA activities have no proceeds/reut.) (Can use just the expense, savings and MILCON cost.) Also considered, and recommended for future inclusion, is safety, morale and welfare. Once these factors are quantified in dollars they would be included under projected savings.

13. As I mentioned before, priorities will be based on net annual benefit.

14. This is the format we used for determining the net annual benefit of a specific MILCON.

15. For those of you who are wondering, why such a complex formula - we could have come up with the same figure using this formula.

16. We chose to use the more involved formula, because by utilizing this format, we have given visibility to certain data which we will want to periodically review for accuracy.

17. Once we determine the Net Annual Benefit for each MILCON, as shown in these examples, it is just a case of

18. Ranking them in order from the most to least beneficial, to determine priorities. Even though our analysis takes only economic factors into consideration, other factors which might impact on the priority of a specific request are noted. This is so they can be considered by the DPDS Facilities Review Board in reaching its final decision.

19. This example shows a projected loss if the project is approved. As noted we recommend that this request be considered for reevaluation due to anticipated increase in workload resulting from upcoming reorganization.

20. Even though this is just a partial list, it gives you an idea of what the final product looks like. It lists the requests from most to least beneficial. Remarks give the non-economic factors to be considered.

Once again this system seems to be unique to the Defense Property Disposal Service, however the basic principle of prioritizing expenditures based on net benefit is universal, and can be applied at all DLA activities. The use of this priority system forces the requester of a MILCON project to perform an economic analysis prior to the submission of this request.

This system, in itself, is not the total answer to setting priorities and approving MILCON requests. It is a management tool to help managers in the decision making process.

21. This concludes our presentation, are there any questions or comments?

ECONOMIC ANALYSIS

PRIORITIZING MILCON

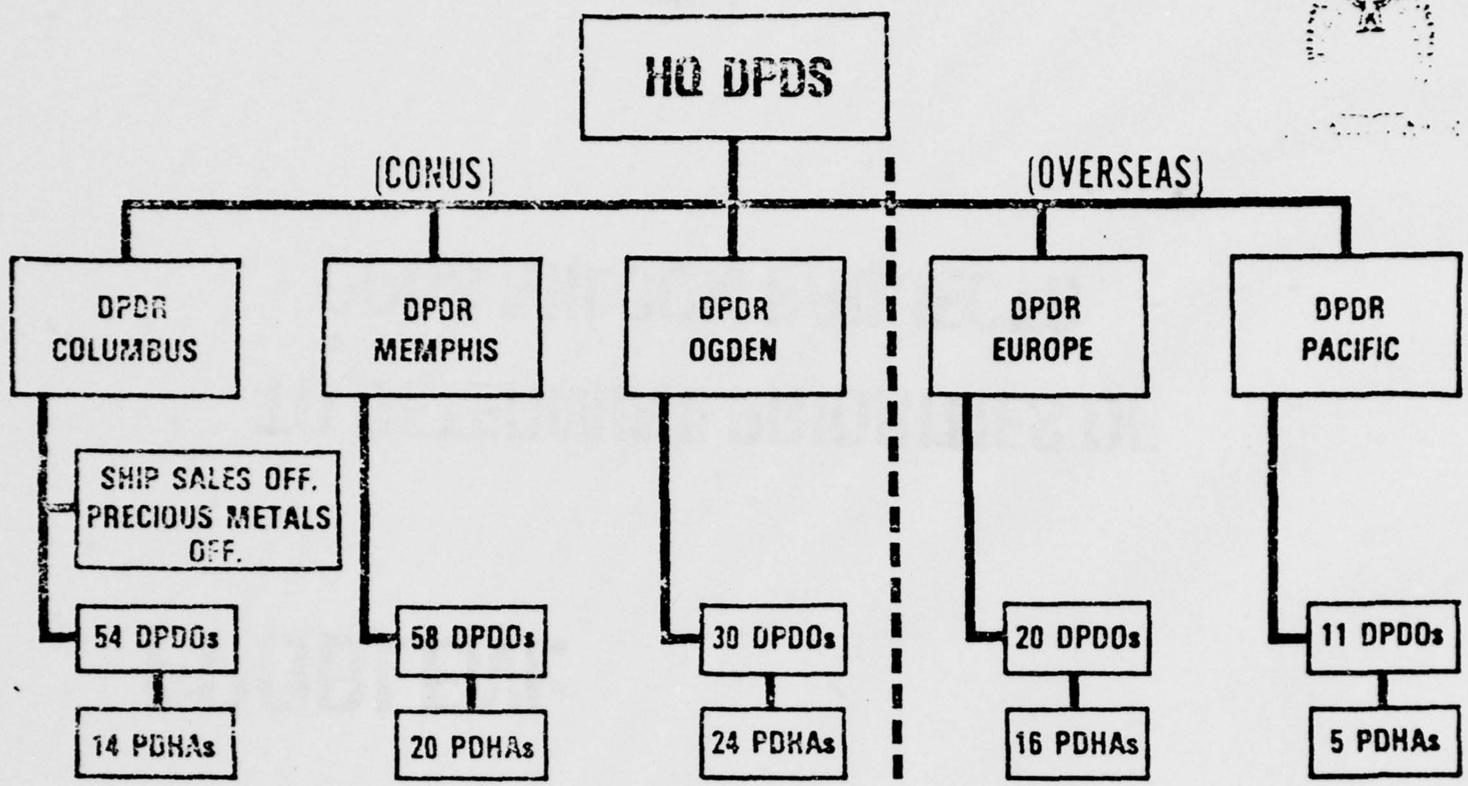
DPDS-OM

CHART 1

DPDS MISSION:

TO ACCOMPLISH THE INTEGRATED MANAGEMENT OF PERSONAL PROPERTY DISPOSAL OPERATIONS WORLDWIDE INCLUDING REUTILIZATION OF SERVICEABLE ASSETS IN SUPPORT OF THE MILITARY SERVICES AND OTHER AUTHORIZED CUSTOMERS.

CHART 2



FIELD ACTIVITIES	CONUS	O/S	TOTAL
SECONDARY LEVEL	3	2	5
TERTIARY LEVEL	144	31	175
QUATERNARY LEVEL	58	21	79
TOTALS	205	54	259

CHART 3

PROBLEM:

TO DETERMINE PRIORITIES OF DPDS MILCON PROJECTS.

CHART 4

PRESENT SYSTEMS OF PRIORITIZING MILCONS

- BASED ON WORKLOAD/PAST PROFIT
- PRIORITIZED BY EACH REGION
- PRIORITIZED AT DPDS HQ BY TYPE OF CONSTRUCTION

CHART 5

WORKLOAD/ECONOMIC DATA

79 MILCON

DPDO	LINE ITEM		SHORT TONS		PROFIT		SUGG PRIORITY LISTING	COST (000)
STEWART	10,380	9	1,087	8	48,613	9	(10)	429
KEESLER	17,097	5	845	9	103,517	8	(8)	478
BELVOIR	29,941	4	2,741	6	114,000	7	(6)	610
HOMESTEAD	10,833	8	1,102	7	0	10	(9)	210
LEONARD WOOD	13,454	7	4,471	4	384,000	2	(3)	324
SILL	33,692	3	3,433	5	125,633	6	(4)	299
SELFRIDGE	15,889	6	555	10	230,000	5	(7)	1,720
ALAMEDA	97,698	1	13,671	1	909,000	1	(1)	900
McCLELLAN	6,987	10	7,276	2	239,000	3	(5)	1,200
LEWIS	54,898	2	5,963	3	231,000	4	(2)	700

CHART 6

FACILITY DEFICIENCY PRIORITY RATING GUIDE

(1) REQUIREMENTS ESSENTIALITY FACTOR	POINTS
DIRECTED BY OSD OR HIGHER AUTHORITY	30
DIRECTED BY DLA DIRECTOR/DPDS COMMANDER	27
STATE AND LOCAL GOVERNMENT REQUIREMENT. (NORMALLY POLLUTION ABATEMENT OR TRAFFIC ORIENTED.)	24
COMMITMENT BY DLA (CONGRESSIONAL AND MILITARY DEPARTMENT).	21
HIGHER ESSENTIAL, CANNOT BE DEFERRED	27
ESSENTIAL - SHOULD NOT BE DEFERRED. BASED ON FACTORS OTHER THAN OPERATIONAL.	18
DESIRABLE - CAN BE DEFERRED.	6
(2) ECONOMIC PAYBACK FACTOR	
1 YEAR OR LESS	30
1-3 YEARS	27
3-5 YEARS	24
5-10 YEARS	18
OVER 10 YEARS	0

CHART 7

FACILITY DEFICIENCY PRIORITY RATING GUIDE (CONT'D)

(3) <u>SAFETY-SECURITY & REALIABILITY FACTOR</u>

(INCLUDES FIRE, TRAFFIC, INDUSTRIAL SECURITY, EMERGENCY POWER.)

SEVERE	20
MODERATE	10
MARGINAL	4

(4) <u>MORALE-WELFARE FACTOR</u>

(INCLUDES ALL PERSONNEL RELATED ITEMS NOT OTHERWISE COVERED, SUCH AS: LUNCH ROOMS, RESTROOMS, HEALTH CLINICS, LIGHTING, AND OTHER SIMILAR REQUIREMENTS.)

SERIOUS	20
MODERATE	10
MARGINAL	4

CHART 8

DPDS FACILITIES REVIEW BOARD PRIORITIES

MILCON

PRIORITY	
1	Open Storage
2	Covered Storage
3	Scrap Bins
4	Restrooms/Latrines
5	Scales
6	Docks/Ramps
7	Flammable Storage
8	Security Cage
9	Heating/Cooling
10	Interior Lighting
11	Railroads
12	Sprinkler Systems
13	Security Fencing
14	Security Lighting
15	Administrative Areas
16	Roads and Parking Lots

The above ranking sequence was also influenced by the DPDO's percentage of requirements, i.e., if a DPDO had 80% of his required open storage his request for the remaining 20% would not be as critical as a DPDO's request for covered storage if he currently had only 20% of his covered storage requirement available.

CHART 9

IMPROVED SYSTEM OF PRIORITIZING DPDS MILCONS

- MANAGEMENT CONTROL DIVISION TASKED WITH DEVELOPMENT OF MODEL
- ECONOMIC FACTORS

CHART 10

CONCEPT OF MILCON MODEL

- MORE COMPREHENSIVE DATA
- QUANTIFICATION OF RELEVANT FACTORS
- DOLLARS AS A COMMON DENOMINATOR
- MAXIMIZING DOLLAR RETURNS – BOTH SALES PROCEEDS & REUTILIZATION
- MINIMIZING OPERATING EXPENSES – E.G. PAYROLL, EQUIPMENT MAINTENANCE, ISA COSTS
- OBTAIN OPTIMUM NET ANNUAL BENEFIT

CHART 11

FACTORS CONSIDERED

A. PROJECTED GROSS PROCEEDS (W/O MILCON)

B. PROJECTED $ VALUE REUTILIZED (W/O MILCON)

C. PROJECTED EXPENSES (W/O MILCON)

D. COST OF MILCON

E. PROJECTED IMPROVED PROCEEDS (W/MILCON)

F. PROJECTED IMPROVED REUTILIZED ($) (W/MILCON)

G. PROJECTED SAVINGS (W/MILCON)

CHART 12

NET ANNUAL BENEFIT

NET RETURN (W/MILCON)

NET RETURN (W/O MILCON)

CHART 13

MILCON ANALYSIS

DPDO_______________________________________ MILCON: FY ______

A. Projected Gross Proceeds FY ______ (w/o MILCON)
B. Projected $ Value Reutilized FY ________ (w/o MILCON)
C. Projected Expenses FY _______ (w/o MILCON)
D. Cost of MILCON
E. Projected Improved Proceeds (w/MILCON)
F. Projected Improved Reutilized ($) (w/MILCON)
G. Projected Savings (w/MILCON)

X. Net Return (w/MILCON) = (A + E) + (B + F) - D/5* - (C - G)

Y. Net Return (w/o MILCON) = A + B - C

Z. Net Annual Benefit = Net Return (w/MILCON) - Net Return (w/o MILCON)

*MILCON costs prorated over 5 years

CALCULATIONS:

REMARKS:

CHART 14

NET ANNUAL BENEFIT

$$E + F - D/5 + G$$

D. COST OF MILCON

E. PROJECTED IMPROVED PROCEEDS (W/MILCON)

F. PROJECTED IMPROVED REUTILIZED ($) (W/MILCON)

G. PROJECTED SAVINGS (W/MILCON)

CHART 15

$$X = (2{,}808{,}000 + 1{,}300{,}000) + (9{,}434{,}000 + 660{,}000) - 1{,}702{,}000/5$$
$$- (1{,}091{,}000 - 180{,}000)$$

$$X = \underline{4{,}100{,}000} + \underline{10{,}094{,}000} - 340{,}400 - \underline{911{,}000}$$

$$X = 12{,}942{,}600$$

$$Y = \underline{2{,}808{,}000} + \underline{9{,}434{,}000} - \underline{1{,}091{,}000}$$

$$Y = 11{,}151{,}000$$

$$Z = 12{,}942{,}600 - 11{,}151{,}000$$

$$Z = \underline{\underline{1{,}791{,}600}}$$

CHART 16

MILCON ANALYSIS

DPDO Kaiserslautern MILCON: FY 79

A. Projected Gross Proceeds FY 77 (w/o MILCON) 2,808,000
B. Projected $ Value Reutilized FY 77 (w/o MILCON) 9,434,000
C. Projected Expenses FY 77 (w/o MILCON) 1,091,000
D. Cost of MILCON 1,702,000
E. Projected Improved Proceeds (w/MILCON) 1,300,000
F. Projected Improved Reutilized ($) (w/MILCON) 660,000
G. Projected Savings (w/MILCON) 180,000

X. Net Return (w/MILCON) = (A + E) + (B + F) - D/5* - (C - G)

Y. Net Return (w/o MILCON) = A + B - C

Z. Net Annual Benefit = Net Return (w/MILCON) - Net Return (w/o MILCON)

*MILCON costs prorated over 5 years

CALCULATIONS:

X = (2,808,000 + 1,300,000) + (9,434,000 + 660,000) - 1,702,000/5 - (1,091,000 - 180,000)

X = 4,100,000 + 10,094,000 - 340,400 - 911,000

X = 12,942,600

Y = 2,808,000 + 9,434,000 - 1,091,000

Y = 11,151,000

Z = 12,942,600 - 11,151,000

Z = 1,791,600

REMARKS:

CHART 17

MILCON ANALYSIS

DPDO Selfridge (1) MILCON: FY 79

A. Projected Gross Proceeds FY 77 (w/o MILCON) 745,000
B. Projected $ Value Reutilized FY 77 (w/o MILCON) 1,638,000
C. Projected Expenses FY 77 (w/o MILCON) 545,000
D. Cost of MILCON 1,720,000
E. Projected Improved Proceeds (w/MILCON) 50,000
F. Projected Improved Reutilized ($) (w/MILCON) 300,000
G. Projected Savings (w/MILCON) 200,000

X. Net Return (w/MILCON) = (A + E) + (B + F) - D/5* - (C - G)

Y. Net Return (w/o MILCON) = A + B - C

Z. Net Annual Benefit = Net Return (w/MILCON) - Net Return (w/o MILCON)

*MILCON costs prorated over 5 years

CALCULATIONS:

X = (745,000 + 50,000) + (1,638,000 + 300,000) - 1,720,000/5 - (545,000 - 200,000)

X = 795,000 + 1,938,000 - 344,000 - 345,000

X = 2,044,000

Y = 745,000 + 1,638,000 - 545,000

Y = 1,838,000

Z = 2,044,000 - 1,838,000

Z = 206,000

REMARKS:

(1) Host activity has requested this DPDO to move from its present facilities.

CHART 18

MILCON ANALYSIS

DPDO Keesler (1) MILCON: FY 79

A. Projected Gross Proceeds FY 77 (w/o MILCON) 658,000
B. Projected $ Value Reutilized FY 77 (w/o MILCON) 3,058,812
C. Projected Expenses FY 77 (w/o MILCON) 355,000
D. Cost of MILCON 478,000
E. Projected Improved Proceeds (w/MILCON) 4,720
F. Projected Improved Reutilized ($) (w/MILCON) 35,000
G. Projected Savings (w/MILCON) 1,500

X. Net Return (w/MILCON) = (A + E) + (B + F) - D/5* - (C - G)

Y. Net Return (w/o MILCON) = A + B - C

Z. Net Annual Benefit = Net Return (w/MILCON) - Net Return (w/o MILCON)

*MILCON costs prorated over 5 years

CALCULATIONS:

X = (658,000 + 4,720) + (3,058,812 + 35,000) - 478,000/5 - (355,000 - 1,500)

X = 662,720 + 3,093,812 - 95,600 - 353,500

X = 3,307,432

Y = 658,000 + 3,058,812 - 355,000

Y = 3,361,812

Z = 3,307,432 - 3,361,812

Z = -54,380

REMARKS:

(1) Should be considered for reevaluation due to anticipated increase in workload resulting from upcoming reorganization.

CHART 19

FY 79

PRIORITY OF MILCON
(Economic Analysis)

	1.	Kaiserslautern
	2.	Stewart
b.	3.	Belvoir
	4.	McClellan
a.	5.	Alameda
	6.	Homestead
c.	7.	Selfridge
	8.	Lewis
	9.	Leonard Wood
b.	10.	Sill
b.	11.	Keesler

REMARKS:

a. One of 22 activities scheduled for closure but restored by DPDS Planning Group.

b. Should be considered for reevaluation due to anticipated increase in workload resulting from upcoming reorganization.

c. Host Activity has requested this DPDO to move from its present facilities.

A SIMULATION MODEL OF THE SUPPLY SYSTEM FOR CHILL/FREEZE ITEMS TO DSR EUROPE (KCS) FACILITIES IN GERMANY

by Allan Rosen

BACKGROUND

The simulation model of the supply system for chill/freeze items to DSR Europe was initiated by a request to investigate potential facilities problems and item unavailability at the DPSC Subsistence warehouse facilities at Kaiserslautern, Germany (KCS). Specifically, can KCS support a 30 or 45 day supply level for all items stored and distributed from KCS (see figure 1)?

Subsistence items at KCS are categorized as either chill or freeze items. The chill items include fresh fruits and vegetables among items as cheese, jellies, ham and condiments. As the KCS facilities supports commissary stores as well as military messes, the items stored at KCS consist of both brand name and troop issue items. All items, except offshore (European) produced fresh fruits and vegetables, are transported from the U. S. by containerized van via ship to Europe.

OBJECTIVE

During the last two years many problems affecting the supply of these items to Europe have occurred. Dock strikes, shipping problems, van back-ups in unloading, warehouse handling problems and erratic customer demand have all surfaced as significantly impacting supply effectiveness.

For these reasons the problem of facilities capability was felt to have multiple objectives (see figure 2). As the question pertaining to storage capability at KCS was the most pressing, it was considered the primary objective. The secondary objectives of evaluating item unavailability and network dynamics are more system oriented.

There are basically two phases to the primary objective. The first phase is to estimate what a viable 30 or 45 day supply level for each stocked item should be, then determine whether these levels can be accommodated by the current warehouse. Due to the significant lack of historical customer demand data earlier than January 1977, only 5 months of demand history was available for establishing theoretical 30 and 45 day supply levels.

PROBLEM

DOES DPSC HAVE ADEQUATE STORAGE FACILITIES AT KCS TO SUPPORT A 30 OR 45 DAY SUPPLY LEVEL FOR ALL ITEMS STORED & DISTRIBUTED FROM KCS?

Figure 1

PRIMARY OBJECTIVE

- DETERMINE IMPACT ON THE PHYSICAL STORAGE CAPACITY AT KCS OF ESTABLISHING A 30 OR 45 DAY SUPPLY LEVEL FOR ALL CHILL/FREEZE ITEMS

SECONDARY OBJECTIVE

- ASSESS IMPACT OF NOT IN STOCK (NIS) OCCURRENCES AS A FUNCTION OF INVENTORY SUPPLY LEVEL
- HOW CAN THE SYSTEM ANTICIPATE & CORRECT TO MAINTAIN THE DESIRED OUTPUT?

Figure 2

The next phase considers the fact that material is being moved in and out of the warehouse based on forecasts of demand and supply requirements. This throughput could lead to the condition where the warehouse was overfilled a percentage of the time. By simulating the potential warehouse input and outflow a probability distribution for overfilled potential can be generated.

Similarly, the secondary objectives of assessing item unavailability and system dynamics can be approached by simulating demand forecasts and comparing them to simulated customer demands and potential inventory supply levels.

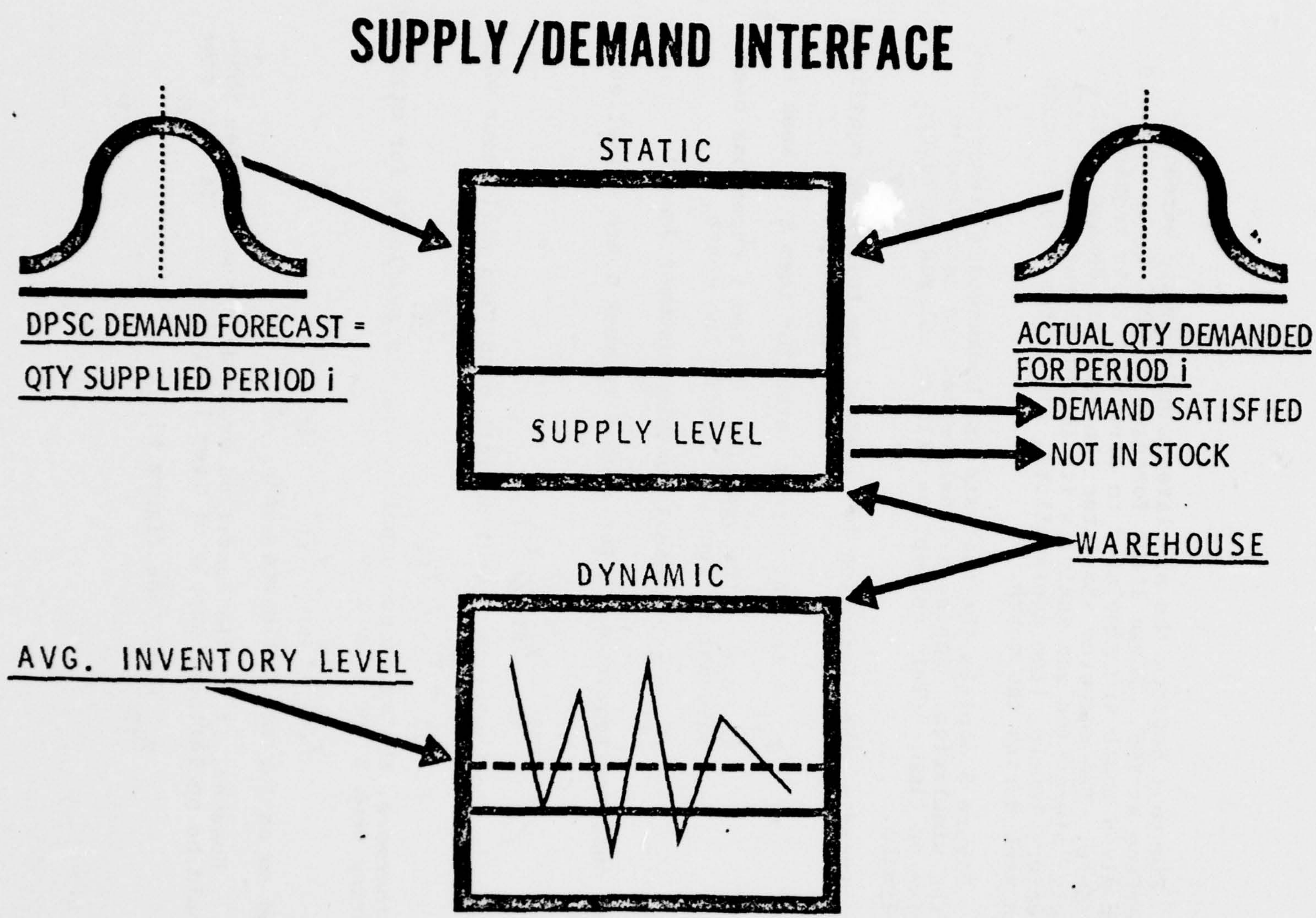
ANALYSIS APPROACH

For each of the 681 active items currently in demand at KCS, 5 months of actual demand history plus item unit volume and weight are input into the computer model. Due to the lack of data, customer demand is assumed to be distributed normally for each item. This is depicted by the bell shaped curve on figure 3 whose height represents the likelihood of a specific demand occurring. (These distributions are created for each item). From the above information and assumptions a simulation was constructed to evaluate the supply/demand interface which occurs. A random variable drawn from the demand distribution, representing the DPSC forecast of the quantity of items to be procured and shipped to KCS, is added to the warehouse supply level on hand The cummulative volume and weight of these available items is then compared to the warehouse capacity constraints.

Moreover, if an item's warehouse supply level plus the incoming quantity is less than the customer quantity demanded, a not in stock (NIS) condition implying unavailability is recorded (figure 3,top).

Initially, the model assumed that each month supply and customer demand arrive in total at the warehouse at the beginning of each month. The lower portion of figure 3 displays the current dynamic representation as deliveries are made incrementally each month.

The current model assumes that the DPSC procured items for a given month are scheduled to arrive in equal weekly phases. Similarly, actual monthly customer demands are also assumed to be uniformly distributed over the month. Additionally each month is assumed to start with a full supply level (30 or 45 day level) for each item.



SUPPLY/DEMAND INTERFACE
STATIC
DPSC DEMAND FORECAST =
QTY SUPPLIED PERIOD i
ACTUAL QTY DEMANDED
FOR PERIOD i
SUPPLY LEVEL
DEMAND SATISFIED
NOT IN STOCK
WAREHOUSE
DYNAMIC
AVG. INVENTORY LEVEL

Figure 3

Figure 4 depicts the simulated supply/demand warehouse interface at KCS. Those items forecast by DPSC to be required over given month are simulated to arrive at their required due date. The computer simulates the customer demand/warehouse supply interaction and analyzes its impact on warehouse space, inventory levels, item availability, and system effectiveness each week during the month.

Figure 5 depicts the analysis and bookkeeping process done in the simulation. Again, all deliveries are considered to arrive on time. (This assumption will be relaxed in future analysis).

Briefly, the simulation is based on the following equations, if

Z_{i1} = initial supply level for item i in week 1.

X_{i1} = ¼ of the quantity of item i which has been forecast as required during the month.

Y_{i1} = ¼ of actual monthly customer demand.

Then customer requirements for item i in week 1 are satisfied when

$$Z_{i1} + X_{i1} \geq Y_{i1}$$

A not in stock or item unavailability condition will occur when

$$Z_{i1} + X_{i1} < Y_{i1}$$

Futhermore, the warehouse supply level now available for utilization during week 2 for item i is

$$Z_{i2} = (Z_{i1} + X_{i1}) - Y_{i1}$$

and so on for the following weeks.

However, if an NIS condition occured in week 1, then there would be no leftover supply of item i for week 2. In this case

$$Z_{i2} = 0 \quad \text{(see figure 5)}$$

KCS SIMULATION - DYNAMIC MODEL

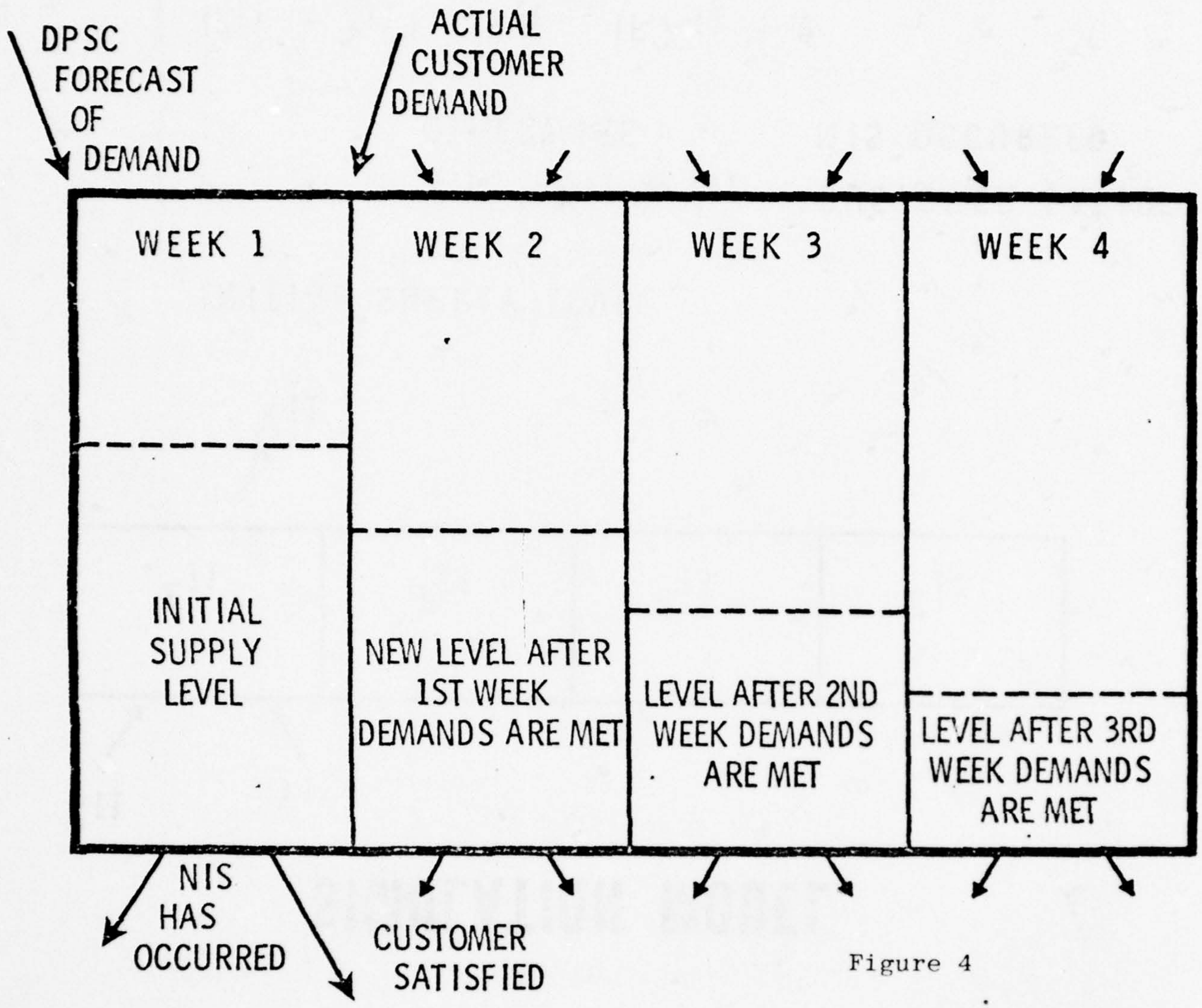
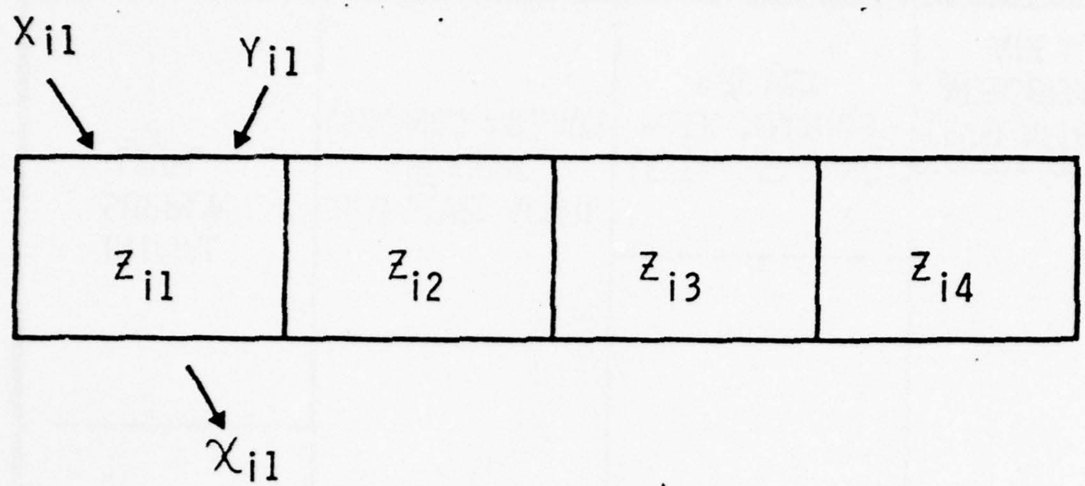


Figure 4

SIMULATION MODEL



$$Z_{i1} = \text{INITIAL SUPPLY LEVEL}$$

$$\chi_{i1} = \begin{cases} 0 & \text{IF} \quad Z_{i1} + X_{i1} \geqslant Y_{i1} \quad \text{; CUSTOMER SATISFIED} \\ 1 & \text{OTHERWISE} \quad \text{; NIS OCCURRED} \end{cases}$$

$$Z_{i2} = \begin{cases} (Z_{i1} + X_{i1}) - Y_{i1} & \text{IF } \chi_{i1} = 0 \\ 0 & \text{OTHERWISE} \end{cases}$$

Figure 5

Currently each month is constrained to start with the original initial (30 or 45 day) supply level. This constraint will be relaxed in future models simulating random arrivals of items and random warehouse supply replenishment.

SIMULATION RESULTS

Figure 6 presents the effects of simulated 30 and 45 day supply levels on warehouse space. For each supply level, the fluctuations in warehouse utilization caused by weekly deliveries and withdrawals is evaluated.

Facilities at KCS are divided into chill space and freeze space. Although the maximum chill capacity* at KCS is approximately 192,500 cubic feet, loading and refrigeration factors reduce this maximum capability by at least 15%. Therefore approximately 163,600 cubic feet is actually available for chill storage. Similarly although freeze capacity at KCS is 420,000 cubic feet, only 348,500 is usable.

In the analysis, chill space at KCS may be further reduced by space required for fresh fruit and vegetables. As only limited data was available for these items, the warehouse chill capability was evaluated with** and without the FF&V.

The simulation analysis indicates that a 30 day supply level for all 127 active chill items would utilize 23.7% of the total chill space facilities. If however the FF&V is included, then 65.1% of the chill facilities would be needed to support a 30 day level.

Similarly, the simulation results indicated that 72% of the freeze capacity of 348,500 cubic feet is required to support a 30 day supply of all 554 active freeze items.

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*Warehouse capcity data were obtained from the Perishable Branch, Supply Operations Division, DPSC-SSP.

**Approximately 66,000 cubic feet of FF&V passes through KCS weekly.

SIMULATION RESULTS

WAREHOUSE CAPACITY

CHILL - 163645 (192523 - MAX)

FREEZE - 348530 (420036 - MAX)

SUPPLY LEVEL*	PERCENT OF CAPACITY**	
		550 TONS (66000 CU FT)
30 DAY	W/O FF&V	FF&V WEEKLY
CHILL	24.7	65.1
FREEZE	71.7	—
95% CHILL	29.6 - 32.5	69.9 - 72.8
95% FREEZE	86.6 - 93.8	—
45 DAY		
CHILL	37.1	77.4
FREEZE	107.6	—
95% CHILL	41.8 - 44.9	82.1 - 85.2
95% FREEZE	122.1 - 129.5	—

*BASED ON 5 MONTHS DEMAND DATA

**BASED ON 85% OF MAX CAPACITY

Figure 6

As the warehouse must also accommodate the incoming items, the analysis predicts that DPSC can be 95% certain that the 30 day chill item inventory level plus the incoming chill items will not use more than 32.5% of the available space without FF&V nor more than 72.8% of the facilities with the FF&V. For the freeze items, the 95% certainty level is at 93.8% of capacity. While 93.8% fill is not an overfill condition, there remains only a marginal space safety factor. Required capacities for a 45 day level are also summarized in figure 6. For a 45 day freeze supply warehouse overfill is virtually certain.

The simulation was constructed in such a manner as to also investigate the effects of supply levels on supply effectiveness. Figure 7 presents these results along with another approach to the problem of warehouse capacity.

Two types of overfill situations were considered. The type 1 overfill is the situation where there is a given supply level in the warehouse and all weekly deliveries are made before any withdrawals are accomplished. The second type of overfill is the reverse situation-all withdrawals are made before any deliveries are accomplished. The true situation is of course somewhere between these two.

Figure 7 presents the probability that either of the above types of overfill may occur. For chill items including offshore FF&V plus CONUS FF&V, the warehouse space should be more than adequate to support all deliveries plus warehouse supply levels (for either 30 or 45 day level). Consequently, the proability of either type situation is zero. Freeze items, however, will present definite problems when a 45 day supply level is utilized.

To assess the impact of inventory supply level on not-in stock occurrences, item availability was simulated as a function of both 30 and 45 days levels. By defining system effectiveness as that percent of items that will fill all demand upon them at any given time, a measure of overall supply effectiveness can be ascertained (figure 7).

Figure 8 outlines the amount of containerized vans needed to transport the simulated subsistence requirements to KCS from CONUS each month. In total between 340 and 466 vans monthly are required. However, as the van off-loading capability at KCS is currently limited to approximately 75-85 vans/week there is a potential van problem.

SIMULATION RESULTS

CHILL

	OVERFILL (1)		OVERFILL (2)	EFFECTIVENESS
		W/FF&V		W/O FF&V
30 DAY	0		0	92%
45 DAY	0		0	96%

FREEZE

	OVERFILL (1)	OVERFILL (2)	EFFECTIVENESS
30 DAY	0	0	96%
45 DAY	100%	100%	98%

Figure 7

VANS REQUIRED

(MONTHLY)

CRITERIA

60% OF VANS ARE 35 FT. WITH 1100 CU. FT. CAPACITY

40% OF VANS ARE 40 FT. WITH 1500 CU. FT. CAPACITY

CHILL

30 - 49 PLUS 92 - 128 (FF&V CONUS) PLUS 28 - 40 (OSP) = 150-217

FREEZE

190 - 249

TOTAL

340 - 466

Figure 8

Figure 9 displays a partial summary of the simulation output for freeze items. For each item (identified by stock code) a 30 day supply level was constructed based upon previous demand history. The associated volume for this level was computed along with the percent of actual warehouse space required. Finally, the unavailability (NIS) factor is simulated and output for each item and the system as a whole.

As warehouse supply levels have impact upon both overfill potential and item unavailability tradeoffs can be made between space requirements and unavailability (NIS) levels. By selectively reducing supply levels for items which already have low NIS occurrences, the space vacated can be used to store a larger quantity of those items whose unavailability be currently unacceptable. Therefore, an item manager by asking the simulation specific "what if" questions on item supply, forecast changes and warehouse facilities should be able to create effective supply to customers while maintaining low warehouse overfill potential.

FUTURE ANALYSIS

Figure 10 shows the flow of subsistence supply from customer requirements through DPSC to vendors and finally to the distribution facilities in Europe-Felixtowe in England, KCS in Germany, BCS in Germany, and CADIZ in Spain. To assess the impact of the dynamics of this stochastic system of time dependent events a complete system simulation has been proposed. This total simulation should provide more definitive answers on immediate and future potential problems which may affect system effectiveness.

CONCLUSIONS

Throughout this paper an adequate inventory supply level was continously defined to be a 30 or 45 day level for every item. This criterion was given as a constraint in the analysis. The analysis of the results indicates however that the most realistic and efficient system would be one establishing a different supply level for each item based on the item manager's ability to forecast item demand and the tradeoffs between holding costs and system capabilities.

COMPUTER OUTPUT

STOCK CODE	QUANTITY (30 DAYS)	STD. DEV.	VOLUME	% TOTAL VOLUME	% TIMES UNAVAIL
67407	12359	2675	1442	.41	.1
67382	6091	10353	178	.05	18.1
67853	732	353	79	.02	1.9
69110	203695	402360	4617	1.32	19.1
61035	10242	1642	567	.16	0

TOTAL VOLUME = 250006 % TOTAL VOLUME = 71.7

TOTAL WEIGHT = 3734 TONS

% TYPE 1 OVERFILL = 0 % TYPE 2 OVERFILL - 0

24 OR LESS ITEMS OUT OF STOCK 100% OF THE TIME EQUATES TO 96% SUPPLY EFFECTIVENESS RATE. THE EXPECTED # OF ITEMS NIS IS 4.8

Figure 9

SYSTEM DESCRIPTION

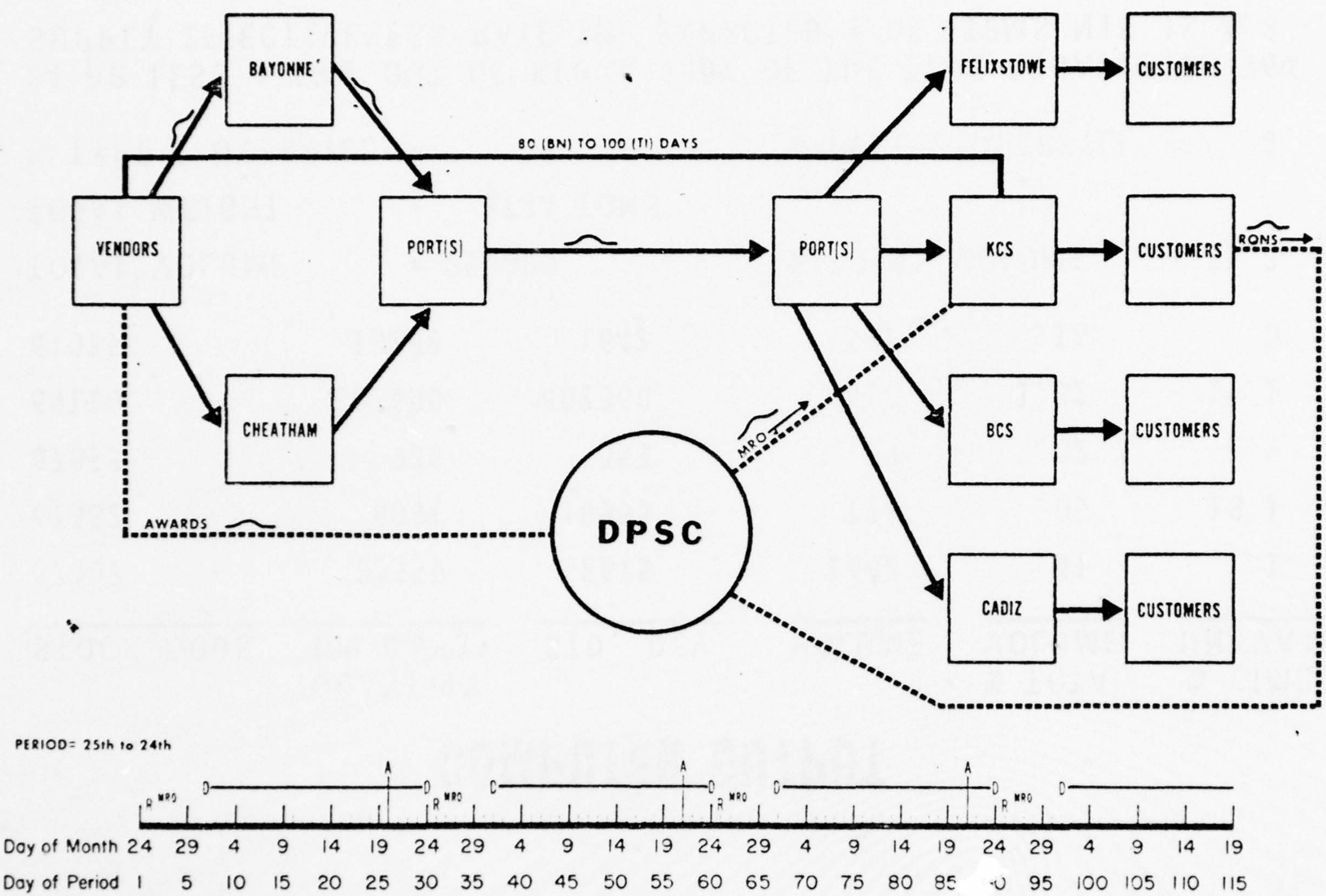

Figure 10

Once these aspects have been established it would then be possible to accurately determine the sufficiency of the storage facility in terms of space and effectiveness.

Therefore, the two recommendations in figure 11 were offered to DPSC.

RECOMMENDATIONS

- POSTPONE ANY DECISION TO ACQUIRE ADDITIONAL PERMANENT STORAGE FACILITIES AS THIS MAY NOT PROVE TO BE THE MOST EFFECIENT SOLUTION
- CONTINUE THE SIMULATION - CONSTRUCTION OF A COMPLETE MODEL

Figure 11

VARIABLE SAFETY LEVEL

PANEL DISCUSSION

The Panel consisted of:

Mr. George Clark, DLA-LO
Mr. George Minter, OASD(MRA&L)
Mr. Robert Bilikam, DESC
Mr. Michael Lipschutz, DPSC

INTRODUCTION

Department of Defense (DoD) Instruction 4140.39, "Procurement Cycles and Safety Levels of Supply for Secondary Items," July 17, 1970, prescribes that a time-weighted, essentiality-weighted, requisitions short variable safety level (VSL) be implemented by the Military Departments and the Defense Logistics Agency. Since implementation of the DoD VSL, several changes have been proposed. Rather than devote the entire hour to a single proposed VSL change, a panel discussion was held. The format was a short presentation by each of the panel members, followed by an open discussion period for questions and comments.

MR. CLARK

Mr. Clark began the discussion by introducing the concept of the variable safety level, in particular, the DoD VSL. He stated that the DoD safety level model was developed by a Joint Service and DLA OR Group and was coordinated by the top echelons of each Service and DLA. The objective of the DoD VSL is "to minimize the total variable ordering and holding costs subject to a time-weighted, essentiality-weighted requisitions short constraint." Simply, this means that we wish to get the material to the customer in the shortest possible time within the constraint of our budget. Or, we wish to most economically minimize the delay which is due to non-availability of stock.

It should be noted that the primary measure of performance used in the DoD VSL is not availability. Rather, it is requisition response time, which is a weighted average of the release time for immediately filled requisitions and the release time for backordered requisitions. In theory, if all backorders were released within one or two days, one could have zero availability and be providing better service to the customer than we are doing today. In practice, requisition response time reflects both availability and time on backorder. If availability goes down, response time goes up and vice-versa. If time on backorder goes down, response time goes down and vice-versa.

The mathematical statement of the DoD VSL is as follows:

Minimize: $$\sum_{i=1}^{n} \left[\underbrace{\frac{P_i \ D_i}{Q_i}}_{\text{ordering cost}} + \underbrace{aC_i(\mu_i + K_i\sigma_i + \frac{Q_i}{2})}_{\text{holding cost}} \right]$$

Subject to:

$$\sum_{i=1}^{n} \frac{.25 \ Z_i\sigma_i^2}{S_i \ Q_i} \left[1 - \exp(-\sqrt{2} \ Q_i/\sigma_i)\right] \exp(-\sqrt{2} \ K_i) \leq \beta$$

where K_i = safety level factor for item i

Q_i = order quantity for item i

μ_i = leadtime demand for item i

a = holding cost rate

C_i = unit price for item i

σ_i = standard deviation of demand over the leadtime for item i

β = number of backorders on file at any random point in time

Z_i = essentiality factor for item i

S_i = average requisition size for item i

D_i = annual demand in units for item i

P_i = procurement cost for item i

n = number of items in inventory

The Method of Lagrange yields the following formula for safety level computation:

$$K_i = -\frac{1}{\sqrt{2}} \ln \left[\frac{S_i \sqrt{2} \ Q_i \ a \ C_i}{.5(-\lambda)Z_i\sigma_i(1-\exp(-\sqrt{2} \ \frac{Q_i}{\sigma_i}))} \right]$$

where $$-\lambda = \sum_{i=1}^{n} \frac{\sigma_i \ a \ C_i}{\sqrt{2} \ \beta}$$

The K_i is a number like 1, 3, 2.7, or even 0. The VSL for an item is equal to the K_i times the standard deviation of demand over the leadtime, i.e., $VSL_i = K_i\sigma_i$.

As can be seen, the safety level for an item is based upon its individual characteristics. The following chart diagramatically shows the general effect on the safety level when given an increase in the given characteristic.

Characteristic	Effect on VSL_i
Leadtime	↑
Variance of demand	↑
Number of requisitions	↑
Demand	↑
Order quantity	↓
Unit price	↓
Average requisition size	↓

MR. MINTER

Mr. Minter was introduced as the present OASD(MRA&L) representative responsible for DoDI 4140.39. Mr. Minter began by addressing zero safety levels which are being produced by DoD VSL. He indicated that the matter of zero safety levels was a concern not only of DLA but of most of the Services, in particular, when the DoD VSL was first implemented. However, all Services and DLA have had improved performance after implementation; improved not only in terms of the objective of reducing response times but even in terms of better availabilities (i.e., number of immediate issues). He closed by enumerating DoD's overall satisfaction with the DoD VSL but also citing DoD's willingness to entertain any suggestions for improvement.

MR. BILIKAM

Mr. Bilikam presented a synopsis of a paper he did on a proposed change to the DoD VSL. The paper has been included as an appendix. In brief, his paper prescribes a mathematical technique for reallocating the requirement for VSL from items which are in long supply to items which are in shorter supply. As presented, this would require a one-time stock fund investment to gain improved performance.

Mr. Minter noted that this additional investment was a stumbling block to any consideration of adopting this proposed change. It was

noted that at the time of stratification, funds are not authorized to the VSL requirement of items in long supply.

DESC was tasked to demonstrate that the funds used for their proposed VSL modification would produce better performance than those same funds used for the present VSL formulation.

MR. LIPSHUTZ

Mr. Lipshutz discussed VSL implementation problems for the DPSC commodities. The following comments were made regarding the Medical commodity:

1. DPSC requested latitude in utilizing the VSL essentiality factor for selected groups of medical items.

2. The Medical commodity was concerned with the many items which had a zero-computed VSL.

Regarding C&T, three comments were made:

1. DPSC is concerned that the lack of an alpha factor in the program oriented item system of C&T requires the approximation of an alpha factor for development of the MAD multiplier.

2. A Mean Absolute Deviation is not now present in the C&T files and will have to be computed from available data.

3. The average requisition size of the VSL computation is not really representative of the C&T requisition distribution, which is distorted by a small number of very large requisitions.

DOD VARIABLE SAFETY LEVEL MODIFICATION
FOR SHIFTING INVESTMENT
FROM ITEMS WITH SURPLUS ASSETS

(Robert C. Bilikam)

1. Background:

The DoD Variable Safety Level Model prescribed in DoDI 4140.39 (reference 1) was implemented in January 1976 at the Defense Electronics Supply Center according to guidance published in July 1972 (reference 2) by the Defense Logistics Agency. The model of backorder distribution was adopted from the Air Force Logistics model discussed by Presutti and Trepp (reference 3). This model essentially assumed a double Laplace distribution of lead time demand to approximate the tails of a normal distribution with the expected backorder expression derived from an argument presented by Hadley and Whitin (reference 4). The resulting expected backorders expression was used in a constrained optimization to minimize the sum of the holding and ordering annual costs subject to the constraint on total expected backorder lines. The safety level formulation was derived by optimizing with respect to the mumber of standard deviations of lead time demand contained in each individual item safety level. The minimum safety level was to be zero, with maximum safety level not exceeding a lead time demand quantity.

2. Problems Encountered:

Experience with the safety level over one year has indicated the following operational difficulties with the DoD Variable Safety Level:

a. Items with surplus assets (and therefore will not buy for a long period) are receiving large safety level investment in competition with items which will buy shortly and therefore have a significant impact on the future backorder posture. This problem arises because the expected backorder formulation does not recognize asset levels for individual items. Other characteristics than assets therefore determine the item safety level (such as price, requisition size).

b. Items with small procurement cycles and/or very low assets which have a crucial impact on the future back-order posture are not receiving a useful safety stock, because they are losing investment to the items with surplus assets (most of which have large procurement cycles).

c. Items with surplus assets that otherwise have favorable characteristics for large safety levels are receiving inordinately large safety levels which in any case are unnecessary for a reasonable interpretation of safety stock. Some safety levels are far in excess of 100 days stock on items with normal lead times (6-9 months).

3. Mathematical Formulation of Individual Item Constraints:

The definitions of the mathematical symbols are contained in Appendix A. The methodology for correcting the problems encountered is as follows. The safety level is to be constrained for individual items which are defined by their assets in relation to the reorder point plus procurement cycle. Specifically, two sets of items are to be identified for constraint of safety level:

SET [1]:

$$ui + XDi + Qi + LDi \leq [\text{assets on item } i],$$

$$i \in [1]. \quad L \geq 0.$$

This set of items have assets greater than the total procurement objective plus L years additional stock, where L may be zero. Thus the items are not expected to buy for [Qi/Di + L] years into the future. The procurement objective is defined with the safety level set at some maximum value XDi [X/365 days of stock]. The unconstrained safety level would be larger than XDi:

$$ki\sigma i > XDi, \; i \in [1].$$

SET [2]:

Similarly to the above, Set [2] is defined to be the items for which:

$$[\text{Assets on Item } i] \leq ui + Qi + YDi, \; i \in [2].$$

The items in Set [2] have assets lower than the procurement objective defined with a minimum safety level YDi [Y/365 days of stock]. The unconstrained safety level would be smaller than YDi:

$$0 \leq k_i \sigma_i < YD_i.$$

4. Solving the Additionally Constrained Problem:

The objective function (annual cost with constraints) becomes:

$$K = \underbrace{\sum \frac{A_i D_i}{Q_i}}_{\text{Order Cost}} + \underbrace{\sum a_i C_i \left(u_i + k_i \sigma_i + \frac{Q_i}{2}\right)}_{\text{Holding Cost}}$$

$$- \underbrace{\lambda \left[\frac{.5}{2} \frac{Z_i \sigma_i^2}{Q_i} \left(1 - \exp\left(-\sqrt{2}\,\frac{Q_i}{\sigma_i}\right)\right) \exp\left(-\sqrt{2}\,k_i\right) - B\right]}_{\text{Constraint on Backorders. } (\leq B)}$$

$$- \underbrace{\sum_{i \in [1]} \theta_i \left(k_i \sigma_i - XD_i\right)}_{\text{Constraint on Set [1] Items}} \quad - \underbrace{\sum_{i \in [2]} \theta_i \left(k_i \sigma_i - YD_i\right)}_{\text{Constraint on Set [2] Items}}$$

The Lagrangian Multiplier $-\theta_i$ for each item in Sets [1] and [2] has been added, with the values implied by "added cost:"

$$-\theta_i > 0 \text{ for } i \in [1],\ XD_i < k_i \sigma_i$$

$$-\theta_i < 0 \text{ for } i \in [2],\ YD_i > k_i \sigma_i$$

$$\theta_i = 0 \text{ otherwise.}$$

The objective function is now to be optimized (minimize total annual cost) by differentiation and setting the resulting expressions equal to zero. This results in:

$$(1) \quad \exp\left(-\sqrt{2}\,k_i\right) = \frac{(a_i C_i - \theta_i)\, Q_i \sigma_i}{-\left(\frac{.5}{2}\right) \sqrt{2}\, Z_i \sigma_i^2 \left(1 - \exp\left(-\sqrt{2}\,\frac{Q_i}{\sigma_i}\right)\right)}$$

the normal unconstrained solution for ki when $-\theta = 0$.

$$(2) \quad -\lambda = \sum \frac{(aiCi - \theta i)\sigma i}{\sqrt{2}\,B},$$

the normal expression for - when all -0i's = 0.

$$(3) \quad ki = \frac{XDi}{\sigma i} \; i\varepsilon \; [1], \quad k_i = \frac{YDi}{\sigma i} \; i\varepsilon \; [2]$$

The last expression indicates items in Sets [1] and [2] have their constrained value of safety level.

The system constant defining the level of possible investment is:

$$(4) \quad SC = \sum_i (aici - \theta i)\sigma i,$$

which has its normal value if all $-\theta i$'s = 0. The direction of addition and subtraction from this level of investment is seen to be correct, since cutting back safety level in Set [1] adds back investment potential, and increasing safety level in Set [2] reduces investment potential.

Substituting (2) into (1) and (3) into the result for ki gives (5):

$$ai\,(Ci) - \theta i = \frac{(SC)\; Zi\sigma i\; (1-\exp(-\sqrt{2}\,\frac{Qi}{\sigma_i}))\; \exp\,(-\sqrt{2}\,\frac{XDi}{\sigma_i})}{4QiB}$$

for $i\varepsilon$ [1], with Y replacing X for $i\varepsilon$ [2].

$$aiCi - \theta i > 0.$$

It is assumed that the SC is available from the previous period of calculations to use in the next period.

5. Conclusions:

a. The value of $-\theta i$ is positive when reducing safety level and negative when increasing safety level indicating increased annual cost. However, neither the real backorders nor the real holding cost increase with decreasing safety levels on items with surplus assets (Set [1]). The real holding cost is increased by increasing Set [2] safety levels, but the real backorders are reduced.

b. The method provides a simple correction device for calculating potential investment adjusted optimally considering the nature of the desired revision. A little experience with the new method of calculations can quickly establish simple relationships for control of investment compared to the old method.

c. The unconstrained safety levels may be raised by reducing safety levels on items with surplus assets and adjusting the system constant (SC). After the initial period, there may be little need for increasing many safety levels to the minimum safety level specified. Thus, the overall safety level representing the same total investment will be much more usefully employed.

REFERENCES

1. DoD Instruction 4140.39, "Procurement Cycles and Safety Levels of Supply for Secondary Items," July 17, 1970.

2. HQ DLA Guidance for Implementation of Time Weighted - Essentiality Weighted Requisitions Short Variable Safety Level, DLA-LO (Operations Research and Economic Analysis), July 1972.

3. "More Ado About EOQ," V. J. Presutti, Jr., and R. C. Trepp, Operations Research and Economic Analysis Technical Memorandum Number 9, Operations Analysis Office, HQ Air Force Logistics Command, WPAFB, Dayton, Ohio, June 1970.

4. Analysis of Inventory Systems, G. Hadley and T. Whitin, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1963, Especially pp 183-188.

APENDIX A

Definitions of Mathematical Symbols Used in Safety Level Model.

i = Index for item of supply.

D_i = Annual demand for Item i.

μ_i = Lead time demand for Item i.

C_i = Standard cost for Item i.

A_i = Ordering cost per order for Item i (a constant in some systems).

σ_i = Standard deviation of lead time demand for Item i.

Q_i = Procurement cycle (Economic Order Quantity in most cases) for Item i.

a_i = Holding cost rate/year for Item i.

Z_i = Essentiality/average requisition size Item i.

k_i = Number of standard deviations of lead time demand in the safety level (SLi) for Item i.

λ = Overall LaGrangian Multiplier for the constraint added to the annual cost criterion function. Can be interpreted as the implied annual cost per line of backorder (unit on backorder if Zi not dependent on average requisition size).

θ_i = Individual LaGrangian Multiplier for the constrained safety level of an item. This is an annual cost per unit of deviation from unconstrained safety level.

X = A factor against annual demand to express the safety level on items with surplus assets and large unconstrained safety levels. The safety level for these items is SLi = XDi.

Y = A similar factor to X for increasing safety level on items with "low" assets and a zero or low unconstrained safety level. SLi = YDi.

B = Backorder target (allowed for system).

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MODIFICATION OF

DOD VARIABLE SAFETY LEVEL

TO SHIFT INVESTMENT

FROM ITEMS WITH SURPLUS ASSETS

BACKGROUND:

1. MODEL OF DOD VARIABLE SAFETY LEVEL SPECIFIED BY DODI 4140.39, JULY 1970.

2. HQ DLA GUIDANCE FOR IMPLEMENTATION - TIME WEIGHTED REQUISITIONS SHORT MODEL PUBLISHED JULY 1972.

   a. USES AFLC MODEL BY PRESUTTI - TREPP.

   b. ASSUMES DOUBLE LAPLACE (TAILS) DISTRIBUTION OF LEAD TIME DEMAND.

   c. USES EXPECTED BACKORDER EXPRESSION BASED ON STEADY STATE ANALYSIS OF INVENTORY POSITION (WITH TRANSITION STATES).

3. MODEL IMPLEMENTED AT DESC JANUARY 1976.

PROBLEMS ENCOUNTERED:

1. ITEMS WITH SURPLUS ASSETS (OVER PROCUREMENT OBJECTIVE) ARE RECEIVING LARGE SAFETY LEVEL INVESTMENT.

2. ITEMS WITH SMALL PROCUREMENT CYCLES AND/OR LOW ASSETS ARE NOT RECEIVING USEFUL SIZE SAFETY LEVEL (0 TO 30 DAYS STOCK).

3. ITEMS WITH SURPLUS ASSETS ARE RECEIVING INORDINATELY LARGE SAFETY LEVELS - (OVER 100 DAYS STOCK) (SL - 0 TO LEAD TIME DEMAND).

INDIVIDUAL ITEM GROUPINGS

1. ITEMS WITH SURPLUS ASSETS.

$$u_i + XDi + Q_i + LD_i \leq \text{ASSETS (INV. POS.)}$$

XD_i = MAXIMUM SAFETY LEVEL

$ki\,\sigma i > XDi \qquad iE \quad \text{SET [1]}$

L = YEARS OVER PROCUREMENT OBJECTIVE ≥ 0

2. ITEMS APPROACHING BUY POSITION.

$$u_i + YDi + Q_i \geq \text{ASSETS}$$

YDi = MINIMUM SAFETY LEVEL

$ki\,\sigma i < YDi \qquad iE \qquad \text{SET [2]}$

MODEL

ANNUAL COST EQUATION

1. ORIGINAL MODEL

$$K = \underbrace{\sum_i \frac{AiDi}{Qi}}_{\text{ORDER COST}} + \underbrace{\sum_i a_i \; Ci \,(ui + ki \,\sigma i + \frac{Qi}{2}}_{\text{HOLDING COST}}$$

$$- \lambda [\quad \sum \frac{.5}{2} \quad \frac{Bi \,\sigma i}{Qi}^{2} \quad (1 - \exp(- \sqrt{2} \; \frac{Qi}{\sigma i})\,)\ \exp(- \sqrt{2}\, ki) - B]$$

BACKORDER CONSTRAINT

2. ADDED CONSTRAINTS

$$- \sum_{i \, E \, [1]} \theta_i \quad (k_i \,\sigma i \;-\; XD_i) \;-\; \sum_{i \, E \, [2]} \theta_i \quad (k_i \,\sigma i \;-\; YD_i)$$

CONSTRAINT ON	CONSTRAINT ON
SET [1] ITEMS	SET [2] ITEMS
(SURPLUS ASSETS)	(ASSETS BELOW
	PROCUREMENT OBJ.)

VALUE OF INDIVIDUAL $- \theta_i$

(1) $- \theta_i = 0$, UNCONSTRAINED SAFETY LEVEL.

(2) $- \theta_i > 0$, $i \in$ SET [1] , SURPLUS ASSETS.

(3) $- \theta_i < 0$, $i \in$ SET [2] , APPROACHING BUY.

(4) $$a_i C_i - \theta_i = \frac{SC \; Z_i \sigma_i \left(1 - \exp - \sqrt{2}\frac{Q_i}{\sigma_i}\right) \exp\left(- \sqrt{2}\frac{XD_i}{\sigma_i}\right)}{4 Q_i B}$$

(5) $$SC = \sum_i (a_i C_i - \theta_i) \sigma_i$$

MINIMIZATION OF COST EQUATION

$$(1)\quad \mathrm{EXP}\left(-\sqrt{2}\ K_i\right) = \frac{(a_i\ C_i - \theta_i)\ Q_i}{-\lambda(\frac{.5}{2})\sqrt{2}\ \ Z_i\ \sigma_i\ \ (1-\exp(\sqrt{2}\ \frac{Q_i}{\sigma_i}))}$$

$$(2)\quad -\lambda = \frac{\sum (a_i\ C_i - \theta_i)\ \sigma_i}{2\ B}$$

$$(3)\quad K_i = \left(\frac{XD_i}{\sigma_i}\right),\ i\ E\ \text{SET}\ [1]\ .\ -\theta_i > 0$$

$$(4)\quad K_i = \left(\frac{YD_i}{\sigma_i}\right),\ i\ E\ \text{SET}\ [2]\ .\ -\theta_i < 0$$

$$(5)\quad SC = \text{SYSTEM CONSTANT}$$

$$= \sum_i (a_i\ C_i - \theta_i)\ .\ \sigma_i$$

CONCLUSIONS

1. INVESTMENT CAN BE RE-ALIGNED FROM SURPLUS ASSET ITEMS (MAX SAFETY LEVEL).

2. INVESTMENT POTENTIAL (SYSTEM CONSTANT) CAN BE INCREASED FOR ACTIVE ITEMS (MINIMUM SAFETY LEVEL).

3. INCREASE AVERAGE UNCONSTRAINED SAFETY LEVEL.

4. SYSTEM SIMPLE TO OPERATE ONCE ITEMS FLAGGED (LEVELS REVIEW).

DLA MANPOWER PLANNING MODEL

by
Michael R. Pouy

The DLA Manpower Planning Model is a computer simulation model that will be used to project shortfalls to future personnel requirements in the Quality Assurance (QA) Directorate of DLA.

The model is currently under development and will be operational by the end of September 1977. The purpose of this paper is to describe the nature of the problem and the approach being taken to seek out a solution.

Until recently the attrition rate in the QA workforce has held steady at approximately 6% per year. However, the number of personnel reaching retirement eligibility has been increasing each year for the past several years, causing the attrition rate to rise to well over 8% this year. Since present hiring and recruitment programs are based on the more stable attrition rates of past years, they are, or soon will be, unable to provide sufficient personnel input to maintain a competent workforce. Thus, the need for some method of approximating future requirements.

Chart I illustrates the distribution of the QA workforce by age. Note the disproportionate number of personnel near the minimum retirement age of 55. The median age is 52; one-half of the workforce is within three years of the retirement age. The average age is 48 and has been increasing each year. Charts similar to this one have been the cause of some concern among managers, and not without reason -- the thought of such a large portion of the workforce simply dropping off the chart can be alarming.

Chart II is based on personnel actions over the past 4½ years and shows the historical probability by age of leaving the workforce. Not unexpectedly, the attrition rate begins to rise near age 50 and rises quite sharply after age 60. Less expected perhaps is the small increase in the attrition rate centered around age 30, where the loss rate climbs to over 10%. Note also that there is a corresponding drop just past age 30 on the age distribution chart. So it is not just people reaching their golden years that we have to worry about -- a large number of personnel reaching age 30 could also push up the attrition rate.

Taking another point of view (Chart III) we can look at the same sort of statistics based on service time rather than on age. The two distributions are similar, although the service time distribution is somewhat more evenly apportioned. The mean and median are both at 22

CHART 1

QA WORKFORCE DISTRIBUTION BY AGE

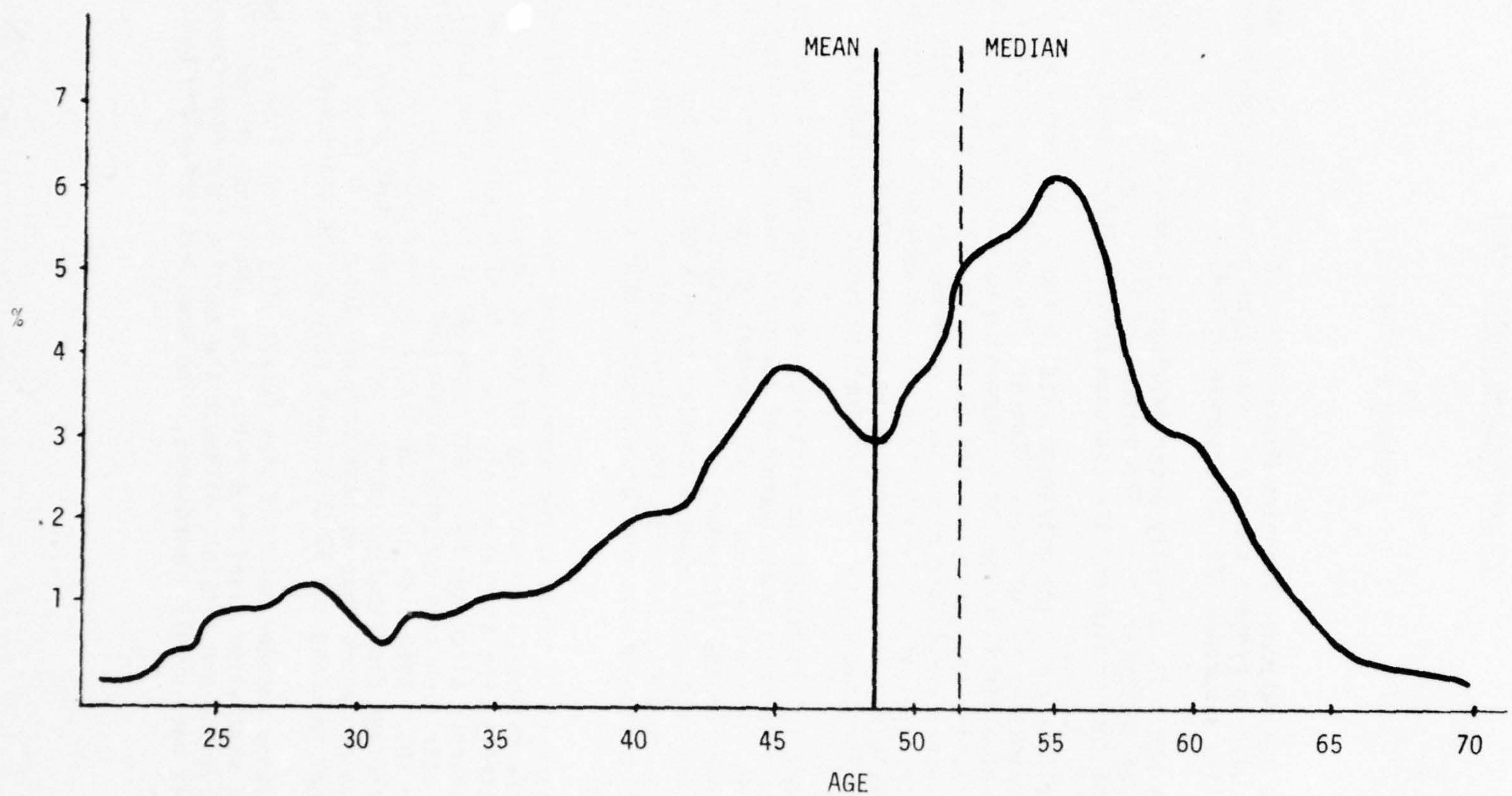


CHART 2

PROBABILITY OF TERMINATING GIVEN AGE

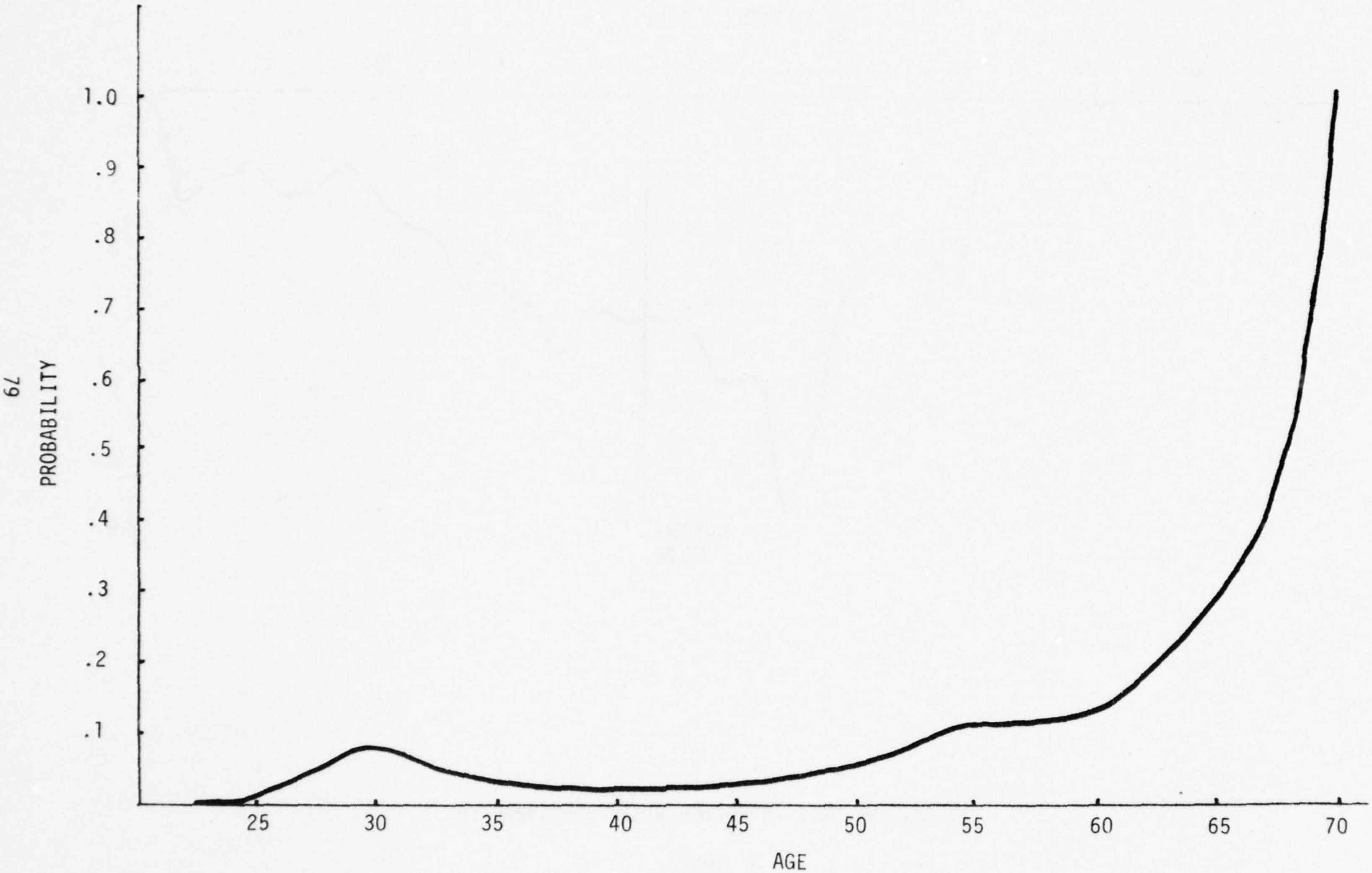
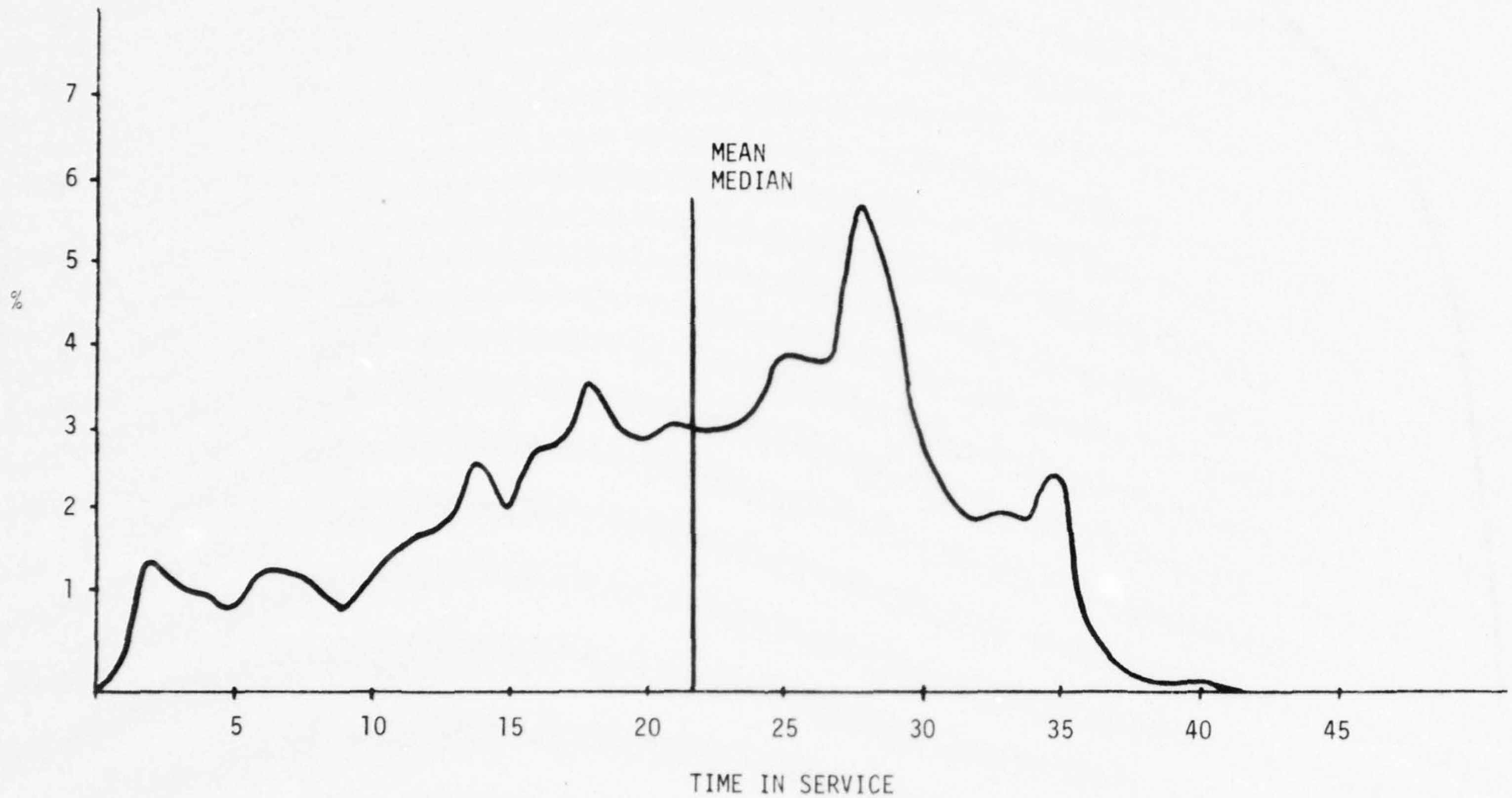


CHART 3

QA WORKFORCE DISTRIBUTION BY TIME IN SERVICE



years. The historical probability of leaving the workforce by service time (Chart IV) is similar to that by age except that the rise in attrition rate seen for age 30 does not appear on this chart.

The point is that a huge portion of the workforce is nearing a point beyond which the likelihood of quitting or retiring is rather high. This is the problem in a nutshell.

Now, the main source of Quality Assurance personnel is a three-year Intern Development Program, which includes both classroom and on-the-job training. The key question is how many interns to recruit into this and other programs in order that the number of graduates each year will approximate the number of losses that year not covered by direct hiring from outside the workforce. The solution is being approached by means of a computer simulation program, written, for the moment, in FORTRAN, which will simulate personnel gains and losses through a planning horizon of about five years. The model will consider a number of elements in simulating these personnel actions (Chart V).

1. Age and Service Time - These are the key drivers for the attrition rate, since they control retirement eligibility.

2. Sex - Preliminary indications are that women tend to leave the workforce at a younger age than do men. Consequently, the number of women in the workforce can be expected to affect the attrition rate.

3. Grade - This has yet to be investigated, but it is not unreasonable to expect grade to influence retirements or other terminations.

4. Other elements, such as education, veteran status, and geographic location, will be investigated. Any of these that can be shown to impact on the attrition rate will be incorporated into the model.

There are two phases to the model: losses and gains. The simulated decision to leave the workforce will be based on the key indicators described earlier. Once that vacancy has been created, the person must be replaced. In essence, the model must "create" a person to replace the existing worker. If the replacement is to be from outside the workforce the model will use stochastic processes to determine the key indicators for that person. Otherwise, the open position creates a requirement for an intern graduating in that year and a corresponding requirement for an intern to be recruited three years previous. This is the answer we're looking for.

Of course, there are other complications to consider. Up to now, we've assumed that all vacancies would be filled. Reductions-in-force and other directed cut-backs must be considered, and we cannot take for granted that all cut-backs can be covered by attrition. In other words, each year the projected personnel levels must be compared, not against the current strength, but against projected requirements input by the operator of the model.

CHART 4

PROBABILITY OF TERMINATING GIVEN SERVICE TIME

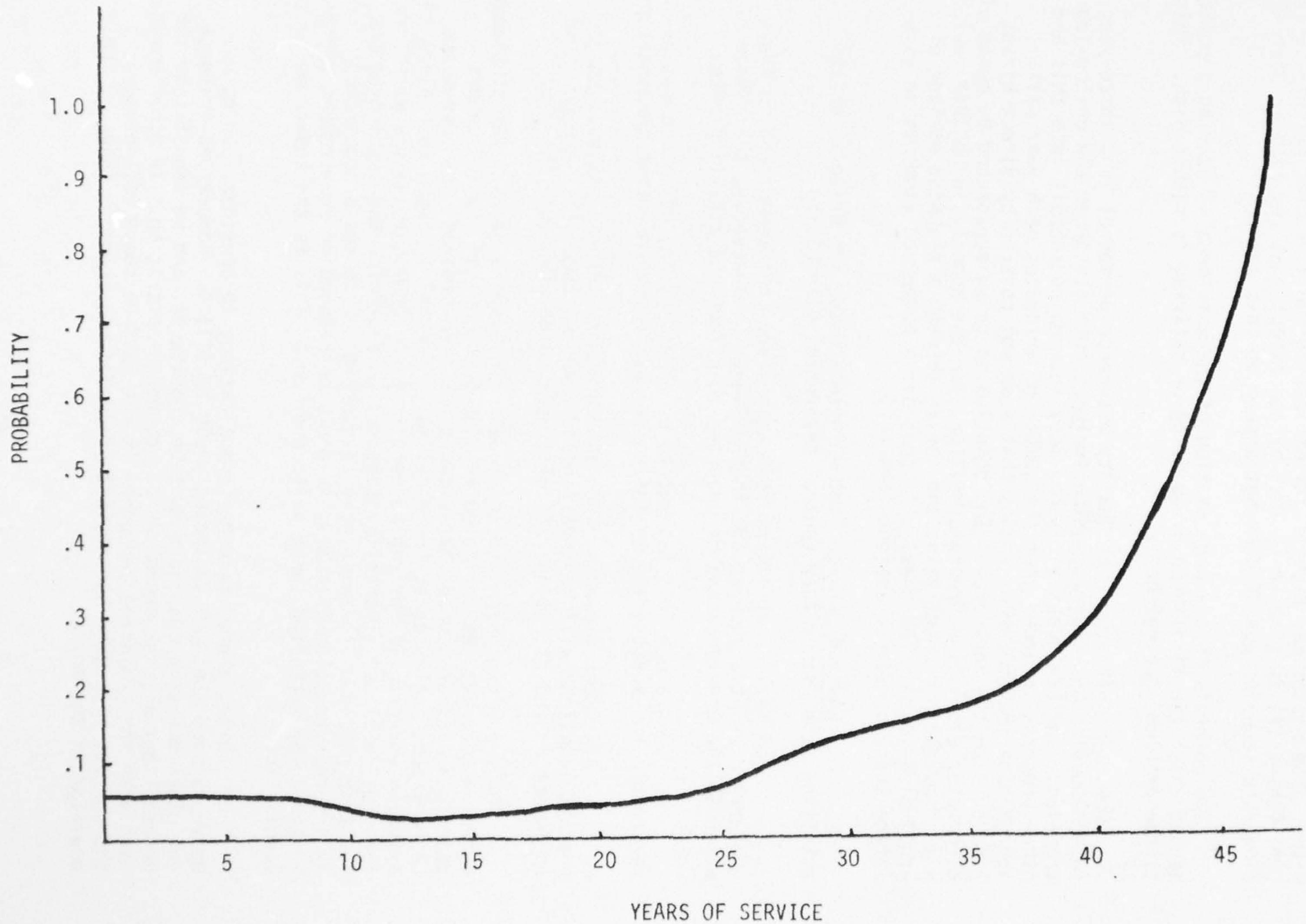


CHART 5

KEY INDICATORS

AGE

SERVICE TIME

SEX

GRADE

EDUCATION

VETERAN

LOCATION

Another problem is the question of retirement incentives which will obviously vary the attrition rate. Although the model cannot anticipate such incentives, it may be able to react to them.

The model, as stated before, is still under development. The model will now be refined to include other appropriate indicators, after which some statistical analysis will be performed to determine confidence limits. The model will be tested and debugged for use in the next recruiting drive for DLA-Q, and then expanded and generalized for use by other DLA staff elements.

COSTS OF CIVIL SERVICE EMPLOYEES
PROCEDURES, POLICY, AND IMPLICATIONS

by Dick Brown

A. INTRODUCTION

Let us begin by considering a simple economic analysis. The cash-flow diagrams shown in Figure 1 depict a cost comparison between an existing manual information system and a proposed automatic data processing system designed to accomplish the same end.

In case some of you are not familiar with the notion of a cash-flow diagram, it is a pictorial technique for representing the nature, magnitudes, and timing of all costs associated with a given alternative. The graduated horizontal lines represent time scales, and the arrows represent costs.

Here, we are comparing the two options over a 10-year project life. The first two years constitute the lead time required to design, test, and implement the ADP system. The estimated operating life of the system is eight years (i.e., project years 3 through 10).

The outcome of the analysis will depend on how the recurring annual savings (project years 3-10) match up against the investment outlay for system design and ADPE procurement. By savings, we mean the cost of the manual data-processing (MDP) clerks who will be eliminated, net of the ADP maintenance, supplies, and equipment service costs which will be needed to support the automated system.

If we have good estimates in hand for all other cost elements, accurate assessment of personnel costs may be critical to a good decision. This brings us to the subject of this presentation, which is the cost of Civil Service employees. We shall consider procedures and policy for determining civilian personnel costs, together with their major impact on economic and budgetary planning.

The scope of this presentation will be limited to General-Schedule and Wage-Board civilian employees. The cost of military personnel services will not be considered.

For those of you concerned about military pay, the latest guidelines of which we are aware are provided by interim change 29 to DSAM 7000.1, page 3-82. For purposes of reference, a copy of these guidelines is reproduced in Figure 2.

B. ADJUSTING PERSONNEL COSTS FOR FRINGE BENEFITS

The key point, of course, is that civil service employees cost the government more than the nominal amount of their annual salaries. This is so because they draw fringe benefits.

AN ECONOMIC ANALYSIS

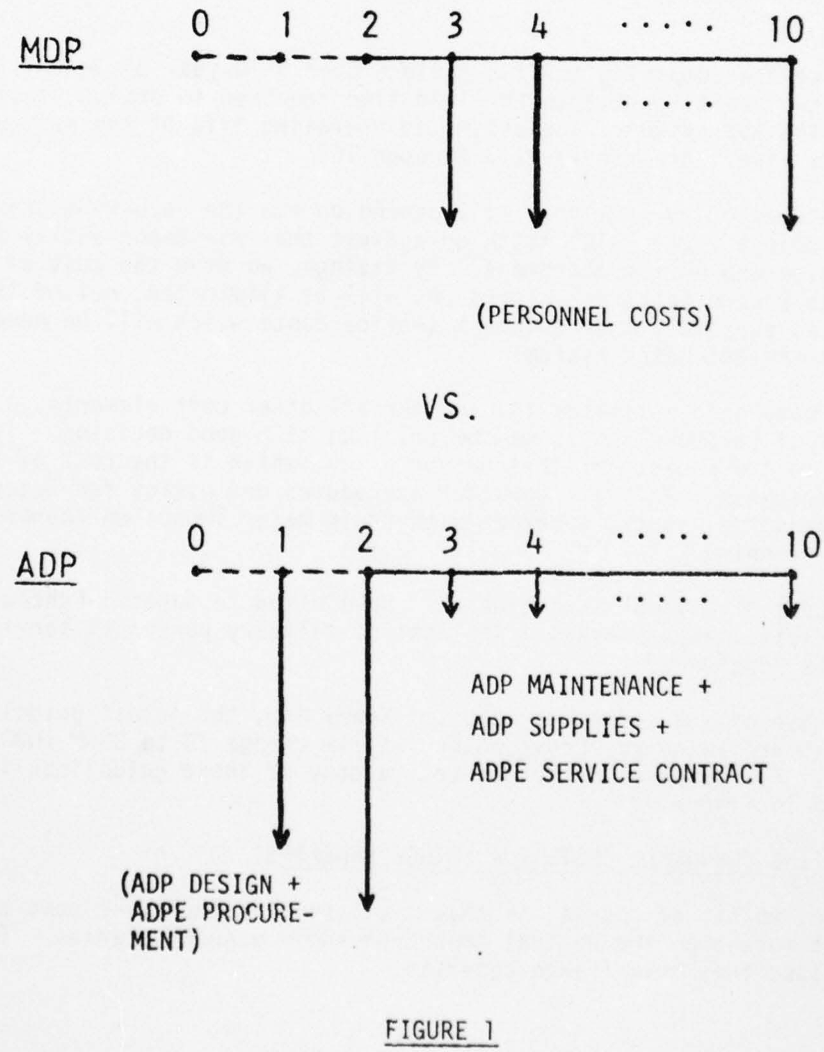


FIGURE 1

Military Standard Rates. The standard rates required to be used for determining the cost of military personnel services are provided below for each pay grade separately for each military service. Rates are shown on a yearly and hourly basis. If daily rates are required for special analyses or studies, multiply the hourly rates by 8. Monthly rates are computed by multiplying the hourly rates by 173.

COMPOSITE STANDARD RATES FOR USE IN
COMPUTING COSTS OF MILITARY PERSONNEL SERVICES

Effective 1 October 1976

Pay Grade	Army		Navy		Marine Corps		Air Force	
	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly	Yearly	Hourly
O-10	46,125	22.22	46,491	22.39	45,690	22.01	50,036	24.10
O-9	43,020	20.72	44,231	21.31	45,284	21.82	47,283	22.77
O-8	43,775	21.09	45,990	22.16	44,676	21.52	46,597	22.45
O-7	39,301	18.93	39,411	18.98	39,581	19.06	40,576	19.54
O-6	35,047	16.88	36,176	17.43	35,007	16.86	36,162	17.42
O-5	28,938	13.94	30,118	14.51	29,866	14.39	30,251	14.70
O-4	24,390	11.75	25,312	12.19	24,921	12.01	25,242	12.16
O-3	20,452	9.85	22,544	10.86	21,488	10.35	21,481	10.35
O-2	16,338	7.87	16,786	8.09	17,248	8.31	16,485	7.94
O-1	11,679	5.62	12,063	5.81	12,212	5.88	11,948	5.76
W-4	22,879	11.02	23,302	11.23	21,686	10.45	27,035	13.02
W-3	18,923	9.12	19,035	9.17	18,941	9.12		
W-2	15,610	7.52	16,279	7.84	16,139	7.77		
W-1	13,534	6.52	14,273	6.87	14,371	6.92		
E-9	19,854	9.57	19,436	9.36	19,991	9.63	19,606	9.45
E-8	16,696	8.04	16,894	8.14	16,393	7.90	16,716	8.05
E-7	14,339	6.91	14,696	7.08	13,818	6.66	14,509	6.99
E-6	11,996	5.78	12,550	6.05	11,551	5.57	12,509	6.02
E-5	10,014	4.83	10,395	5.01	9,670	4.66	10,646	5.13
E-4	8,566	4.13	8,624	4.16	8,205	3.95	9,342	4.50
E-3	7,369	3.55	7,635	3.68	7,162	3.45	7,563	3.64
E-2	7,748	3.73	6,965	3.35	6,758	3.25	6,996	3.37
E-1	6,260	3.02	6,280	3.02	6,177	2.98	6,313	3.04

FIGURE 2

Fringe benefits include three major components: The employee's accrual of retirement eligibility, government contributions to his health insurance, and government contributions to his life insurance. These benefits have a monetary value; it has become customary to express this value as a percentage of annual base pay.

Note that our breakdown of fringe benefits makes no mention of leave. Although the term "fringe benefits" usually subsumes leave in lay usage, for our purposes leave shall remain a distinct category. We shall consider it below.

It is probably easiest to examine the mechanics of fringe benefit costing via an illustration.

EXAMPLE 1: In our ADP/MDP EA, suppose the automated system will eliminate the need for 12 clerks, four GS-4's and eight GS-5's. If we assume a hypothetical fringe benefit rate of 10%, what is the total annual cost of these personnel?

SOLUTION: We assume each clerk to be at step 4 within his grade. In the absence of specific information about steps, this is generally a good assumption. From the current Civil Service salary schedule, we therefore have:

GRADE	STEP	ANNUAL SALARY
GS-4	4	$ 9,147
GS-5	4	$10,233

The cost computations are:

BASE PERSONNEL SALARY COST:

$(4 \times \$9,147) + (8 \times \$10,233) = \$118,452$

TOTAL PERSONNEL COST:

$118,452 x 1.1 (accelerate 10% for fringes)

$= \boxed{\$130.3K}$

C. ADJUSTING PERSONNEL COSTS FOR LEAVE

Now let us turn our attention to this matter of leave. We all lose productive time from the job for various reasons: Annual leave, sick leave, holiday leave, leave without pay, coffee breaks, rest breaks, etc.

QUESTION: Should we factor leave into civilian personnel costs?

ANSWER: It all depends on whether we start with an estimated personnel requirement or an estimated work requirement.

Personnel requirements are stated in terms of numbers and grades of employees. Work requirements are stated in terms of staff-hours or staff-years.

In the fringe-benefit example just considered, we assumed that 12 clerks are currently supporting the manual information system. We did not assume that the present system requires 12 staff-years of clerical work per year. That is to say, we are presently getting by with a staff of 12, given their nonproductive time as well as their productive time. Accordingly, no provision for leave was necessary.

When we start with a work requirement, however, we have to reckon with the fact that within a one-year period, it takes more than one person to do one staff-year of work. In these cases, it is customary to translate the work requirement into a corresponding personnel requirement, multiply the personnel figure by the appropriate annual salary or salaries, and then accelerate for fringe benefits. For this purpose, it is necessary to develop an acceleration factor for leave. Like the fringe-benefit factor, the leave accelerator is usually expressed as a percentage. Consider the following illustration.

EXAMPLE 2: In our ADP/MDP EA, suppose that five staff-years at the GS-12 level will be required for system design during Project Years 1 and 2. Assume a hypothetical fringe-benefit rate of 10% and a hypothetical leave factor of 20%. What is the total personnel cost of this effort?

SOLUTION: An acceleration of 20% for leave means that it takes 1.2 people to accomplish one staff-year of work within a year's time. From the current Civil Service salary schedule, the annual salary of a GS-12, Step 4, is $22,485. The calculation for the total personnel cost follows:

$$5 \times 1.2 \times \$22{,}485 \times 1.1 = \boxed{\$148.4K}$$

Here five staff-years is the work requirement, and

$$5 \text{ staff-years} \times 1.2 \frac{\text{people}}{\text{staff-year}} = 6 \text{ people}$$

is the personnel requirement. As before, the 1.1 factor accelerates personnel base pay to a total personnel cost which includes fringe benefits.

Note that the personnel requirement will be distributed over Project Years 1 and 2 according to the schedule and actual progress of the system design effort. That effort might, for example, require three analysts during Year 1 and three during Year 2; or, it might require just two people during Year 1 and four during Year 2.

In an application such as this, don't make the rather common mistake of adding the 10% fringe-benefit factor to the 20% leave factor to produce a total acceleration factor of 30%. To do so would understate the true personnel cost, as the comparison in Figure 3 shows. In reality the leave and fringe-benefit factors operate in multiplicative fashion. In our example, we are in effect multiplying 1.2 by 1.1. The result, 1.32, indicates a composite leave/fringe acceleration factor of 32%.

THE WRONG WAY

$20\% + 10\% = 30\%$

$5 \times 1.3 \times \$22{,}485 = \boxed{\$146.2K}$

THE RIGHT WAY

$5 \times 1.2 \times \$22{,}485 \times 1.1 = \boxed{\$148.4K}$

THE DIFFERENCE

$100\% + 20\% + 10\% = 1.30 \neq 1.2 \times 1.1 = 1.32$

FIGURE 3

To summarize, if we begin with a personnel requirement, stated as an actual number of people, then in costing this requirement we should accelerate for fringe benefits only.

When we begin with a work requirement, stated in terms of staff-hours or staff-years, we must accelerate both for leave and fringes to obtain the true personnel cost.

D. RECENT HISTORY OF POLICY GUIDANCE FOR LEAVE AND FRINGE-BENEFIT FACTORS

As we indicated, the 20% and 10% leave and fringe-benefit factors used in the above examples were for illustrative purposes only. Now that we have reviewed the mechanics of personnel costing, it is appropriate to ask what policy guidance, if any, exists for leave and fringe benefits.

Since the Department of Defense is an Executive Department, its guidance flows from the Office of Management and Budget (OMB). Up until last year, however, explicit guidance on leave and fringe benefits had never been provided in OMB Circulars No. A-76, A-94, or A-104, which prescribe guidelines for various types of cost comparisons. That preogative was left to the various executive departments and agencies.

In 1969, the Department of Defense (DoD) first issued its Instruction No. 7041.3, entitled "Economic Analysis of Proposed Department of Defense Investments." It prescribed a leave factor of 29% and a fringe-benefit factor of 8.75%. It further specified a joint leave/fringe-benefit factor of 37.75%, which is just the sum of 29% and 8.75%. This is precisely the mistake we cautioned against earlier. The correct joint factor should have been

$$(1.29)(1.0875) - 1.00 = 0.403 = 40.3\%$$

MORAL: Even DoD instructions are not infallible.

In July of 1971, DoD Instruction 4100.33*, "Commercial or Industrial Activities - Operation of," prescribed a leave factor of 20.9% and a fringe-benefit factor of 8.44%. The fringe-benefit factor was broken down as follows:

Retirement/Disability:	7.14%
Health Insurance:	1.00%
Life Insurance:	0.30%
TOTAL:	8.44%

*This instruction number was erroneously cited as 4100.3 in the Symposium presentation.

This same guidance was reiterated in DLA Regulation 4151.3, "Operation of Commercial or Industrial Activities and Use of Contract Services," which was last issued on 16 May, 1972.

This fringe-benefit guidance was on a par with the previous guidance in DoD Instruction 7041.3 (8.44% vs. 8.75%, respectively). But the leave factor was attenuated considerably, from 29% to 20.9%. To our knowledge, there never was an official explanation for this difference.

It should be borne in mind, however, that the DoDI 4100.33/DLAR 4151.3 guidelines formally applied only to cost comparisons of commercial or industrial activities, and not to general economic analyses performed under the OMB Circular No. A-94/DoD Instruction 7041.3 chain. Yet, curiously, the two leave factors (20.9% and 29%) were evidently intended to measure the same thing.

In October 1972, the DoD Instruction 7041.3 was reissued under the title, "Economic Analysis and Program Evaluation for Resource Management." Interestingly, this reissue, which is still in force, contains no explicit leave or fringe-benefit factors.

In a way, perhaps this is reasonable. As with any type of costing, personnel costing is not an exact science. For example, government health and life insurance costs, when expressed as a percentage of base salary, will vary from situation to situation, depending on the grade levels of the employees involved as well as their individual choices with respect to health plans and life insurance. In any particular analysis, if more specific local comptroller data on health and life insurance costs are available, they should by all means be used. Don't feel bound by official guidelines, because that is all they are -- guidelines, to be used only if no better information is at hand.

To repeat, leave and fringe-benefit guidance in the 1972 DoD Instruction 7041.3 was conspicuous by its absence. As a result, the most recent previous guidance gradually evolved into the following rules of thumb: about 9% for fringe benefits and about 20-21% for leave. These rules of thumb gained large acceptance during the period 1972-76.

Then on October 18, 1976, OMB issued its Circular No. A-76 Transmittal Memorandum No. 2. This memo said nothing about leave factors, but it drastically revised fringe-benefit guidance for commercial or industrial activity cost comparisons, as follows:

Retirement	24.7%
Health Insurance	3.5%
Life Insurance	0.5%

The increase in retirement costs from 7% to 24.7% was spectacular, and it created quite a furor.

The old 7% figure had been predicated on government contributions to the Civil Service Retirement Fund, which are put up to match the 7% withheld from our salaries.

The new 24.7% rate came out of a study done by the Civil Service Commission, and was based on a completely different costing rationale. The 24.7% was an estimate of the average increase in the Government's retirement liability to the employee, which arises because of the additional (i.e., current) year that employee is spending on the payroll.

Those who supported this 24.7% retirement cost rate proclaimed that, because of its basis in accrual accounting as opposed to transaction accounting, it was bringing the government into conformance with generally accepted accounting principles for the first time.

Opponents claimed that it was an artificial and transparent attempt to bias commercial/industrial activity cost comparisons in favor of private contractors and against government in-house operations.

Whichever, it has become apparent that the Carter Administration is less bullish on contracting out than was the Ford Administration.

On June 13 of this year, OMB issued Circular No. A-76 Transmittal Memorandum No. 3, which reduced the retirement cost factor from 24.7% to 14.1%. The 3.5% health and 0.5% life insurance guidelines remained in effect. The current total fringe-benefit rate is therefore 18.1%.

The 14.1% retirement guideline retreats from the accrual accounting rationale which produced the previous 24.7% rate. It represents total payments to employee annuitants, reduced by current employee contributions, expressed as a percentage of current Civil Service payroll. It is, however, only an interim guideline. The entire Circular No. A-76 cost comparison methodology is currently under review, and the fringe benefit guidance could well change again within the next 3 to 12 months.

E. RECOMMENDED CURRENT GUIDELINES

It is evident that leave and fringe-benefit guidance is in a transitional stage. Until a final policy emerges, we offer the following suggestions for personnel costing:

1. Use the 14.1% retirement cost rate. Although it has explicitly been designated only for commercial/industrial activity cost comparisons, we submit that personnel cost guidance ought to be consistent across all decision-making contexts.

2. If no better local data are available, use a 3.5% rate for health insurance costs and a 0.5% rate for life insurance costs. This will produce an overall fringe-benefit rate of 18.1%.

3. If your point of departure is a work estimate (i.e., staff-years) rather than a personnel estimate, accelerate for leave as well as fringes. Use a 20% leave factor if you don't have any locally developed estimates.

F. FUTURE IMPLICATIONS

It appears that the days of a 7% government retirement cost guideline are over. Current opinion seems to be gravitating toward a higher figure. This means we are likely to have a permanently higher fringe-benefit factor than the former 8-9%.

All other things being the same, this higher fringe-benefit cost will breed several consequences. We conclude by indicating what several of these consequences might be.

1. The fact that government personnel resources have spontaneously become more expensive will create a twofold substitution effect:

a. First, contract labor will be substituted for government labor in contract vs. in-house operational decisions.

b. Second, even if a contractor alternative is not feasible, there will be a general substitution of capital for labor in-house. Specifically, any mechanized or ADP system which proposes to replace people will appear relatively more attractive in economic analyses accomplished in accordance with OMB Circular No. A-94 and DoD Instruction 7041.3.

2. Because government employees who are considered in commercial/industrial activity cost comparisons or capital investment analyses tend to have lower grades, the average employee grade will increase as proposals to replace such employees become more economically attractive. Thus, the elimination of low-grade employees from the rolls may create administrative difficulties in meeting or staying within average-grade targets.

3. Finally, the new fringe-benefit guidance will have at least a twofold impact on budgetary planning.

a. First, if you have been using an 8.44%, 9%, or other rate for agency funding purposes, you should now be using something like an 11% rate: 7% for retirement, 3.5% for health plans, and 0.5% for life insurance.

b. Second, a schism will appear between fringe-benefit figures used in budgetary documents and economic studies. The 11% rate shown in budgetary documents will no longer reflect the true economic cost of personnel to the Government. This does not reflect any inherent deficiency in budget data, but merely a different perspective between budgeting and economic analysis.

DELPHI METHOD

by David Polinsky

INTRODUCTION

Delphi is defined as a method for obtaining and refining the opinions of a group of people. Three features are associated with the Delphi Method:

1. ANONYMITY

Anonymity is a devise used to reduce the effect of the dominant individual. It is maintained by eliciting separate and private answers to prepared questions.

(Ordinarily, the procedure is carried out by written questionnaire or possibly computer terminals. All interactions between respondents is through formal communication channels controlled by the administrator.)

2. ITERATION AND CONTROLLED FEEDBACK

Controlled feedback is a devise to reduce the introduction of irrelevant or redundant material. A Delphi exercise will usually consist of several iterations where the results of the previous iteration are fed back to the respondents, normally in summarized form.

3. STATISTICAL GROUP RESPONSE

The group opinion is defined as an aggregate of individual opinions on the final round.

HOW TO USE THE DELPHI TECHNIQUE

1. IDENTIFICATION AND SELECTION OF A PANEL OF "EXPERTS"

Several characteristics seem to be important for panels involved in using the Delphi Method.

a. Diversity. The panel members should reflect a wide spectrum of talents. For every aspect of the problem under study, there should be some panel member who is expert in that area. This characteristic diversity of disciplines represented is necessary in order that the panel avoid overlooking or giving perfunctory treatment to fundamentally important facets of the problem.

b. Depth. Some panel members should have a profound understanding of the technical issues involved. They should be considerably more knowledgeable, in a scientific sense, than most people in the world, in their particular speciality. For every major scientific area which is a component of the basic problem, there should be at least one expert with great depth in his subject.

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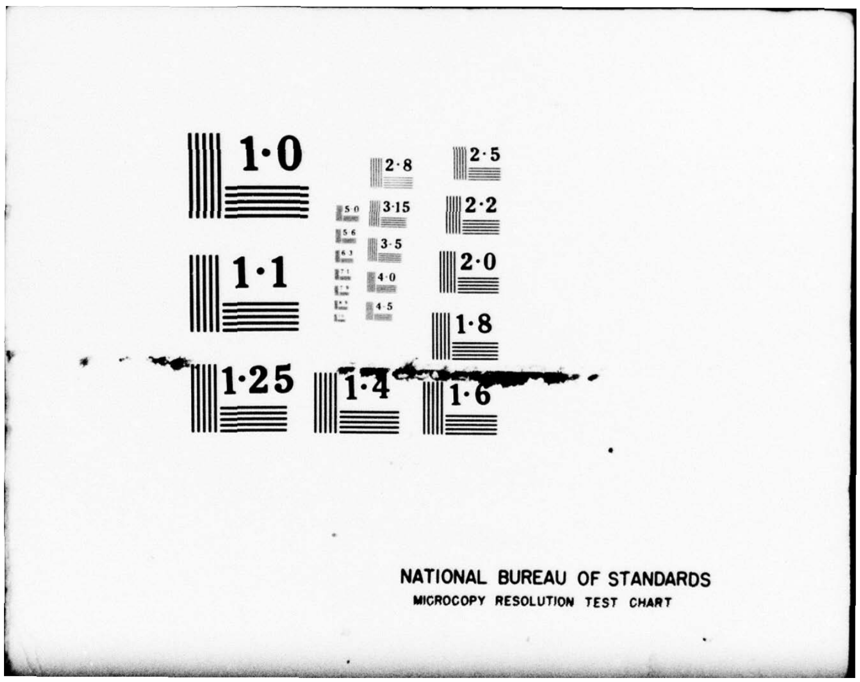
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

c. Breadth. Good panels should probably contain some members who are "system experts." That is, there should be some individuals who are accustomed to thinking on a broad level -- in terms of the interactions of various subsystems. Panel members who have this type of breadth of knowledge are probably better able to predict feasibility and likelihood of large technological development taking place than the layman, who in this case may be some "deeply knowledgeable" scientific expert who tends to be quite narrow in his views and who tends to ignore other developments which will be needed to render developments in his own field meaningful.

2. QUESTIONNAIRE

Questionnaire design is an art which is basically similar for any type of problem and really does not require any further comments at this time.

3. QUESTIONING ROUNDS

The first round questionnaire is sent out to the panel. The responses are then tabulated by the administrator. Some of the responses may be accompanied by explanations from the panelists. The results of the first round are then forwarded to the panelists by some form of statistical feedback, usually involving a measure of central tendency, i.e., mean, mode and/or median, some measure of dispersion or perhaps the entire frequency distribution of responses for each item. If the administrator feels that some of the comments/explanations from the panelists are original in their approach (based on their comments), he can forward these comments with the later rounds.

4. OUTLIERS

Upper and lower quartile responses may be asked by the administrator to provide written justification for their responses. This is done prior to the next round of questioning.

5. ITERATIONS

Iterations with the above type of feedback are continued until convergence of opinion or "consensus" reaches some point of diminishing returns, as determined by the administrator.

6. NUMBER OF ITERATIONS

Generally, only a small number of iterations (3 or 4) will be all that is required. The administrator should avoid, if possible, fixing the number of iterations beforehand.

It should be remembered that the participants do not meet or discuss issues face-to-face and they may be geographically remote from one another.

The individual responses to items are kept anonymous for all iterations. However, the administrator may list the participants in the study.

AREAS OF APPLICATION

Two areas in which the Delphi method is applied are:

1. Long range forecasting, and

2. Areas in which "hard facts" are not known.

PROBLEM AREAS

The Delphi method is not a proven technique. At best it can be considered a process of educated guess work.

DLA FACILITIES PLANNING MODEL

by
Dennis L. Zimmerman

I. INTRODUCTION

Recently the number of facilities operated by DLA has come under scrutiny. The Assistant Secretary of Defense sent a letter to all DoD Components citing the reduced peacetime mission of the Defense Department and the need to reduce the size of their operations. About the same time, the House Appropriations Committee Survey and Investigation (S&I) Staff issued a report which recommended that consideration be given to a single DLA hardware ICP. In response to these documents, a number of studies have been initiated by DLA in the area of facilities planning, including one for ICPs.

The ICP Study involves a direct application of operations research, namely, the development of a mathematical model to determine the optimum number of ICPs. The model was developed as an integer programming model.

Because integer programming is a classical OR technique, I believe a discussion of such a model would be of interest to you. Moreover, this particular model should be of concern to us all because of its potential impact and because of its future possible application to other types of DLA facilities planning.

In this discussion, I would like to cover three areas. They are:

A. The application of integer programming to facilities.

B. The development of the DLA ICP model.

C. The past, present, and future usage of the model.

II. APPLICATION OF INTEGER PROGRAMMING

The application of integer programming to facilities studies is not new. OR analysts have been using integer programming to solve location-allocation problems for the past few years. However, this is our first application of integer programming in ICP planning.

Integer programming itself is a special category of mathematical programming. It can be defined as a mathematical technique for finding the best integer solution from among all solutions of a system of linear equalities or inequalities. There are a number of key words in this definition which I will address to help those of you who are unfamiliar with integer programming.

First, integer programming involves a system or set of linear equalities or inequalities. The form of an integer programming model is

that of a linear equation called the objective function and a set of linear equalities or inequalities called constraints. These together form the system of linear equalities or inequalities in the definition.

The best solution to this system is the solution which yields the maximum or minimum value for the objective function and at the same time satisfies the constraints. Integer programming differs from the widely known linear programming in that it requires that the solution set contain only integer values, that is, the solutions of the variables must be whole numbers.

I will not get into the various mathematical algorithms used in integer programming except to say that a number of these algorithms have been computerized, a fact which has made the application of integer programming practical in today's world.

III. DEVELOPMENT OF DLA ICP MODEL

A. Formulation Narrative. In general, the model defines and relates in mathematical terms all of the costs of ICP management and of possible realignment. The costs are both one-time costs and recurring costs, with the recurring costs being converted to present worth. As previously mentioned, an integer program consists of an objective function, which is to be minimized or maximized, and a set of constraints which might restrict the values of the program variables. In our case, the objective function is the ICP configuration cost function, which is to be minimized subject to real world constraints on ADP, communications, and facilities. The variables in the problem are the assignments of commodities to facilities, the facility usage indicators, the measures of command/support, and the indicators of increases in ADP, communications, and administrative space. The solution of the integer program or the set of values which minimizes the cost function subject to the constraints is the optimal ICP configuration; optimal, that is, in terms of the mathematics of the costs.

1. Objective Function. The objective function is the linear sum of the identified costs, that is:

				Command/		Costs		Costs of		Costs of
Commodity	+	Facility	+	Support	+	of ADP	+	Communication	+	Facilities
Costs		Costs		Costs		Increases		Increases		Space Increases

These costs are represented by the product of collected costs times problem variables.

a. Commodity Costs. The term "commodity," as used in this analysis, refers to a homogeneous grouping of items which are joined together for purposes of management. In these terms, a present day DLA commodity can be split into several commodities for analysis. The total of all of the commodity costs is the sum across all facilities and all commodities of the problem assignment variables times the costs associated with management and realignment of a commodity. The costs are as follows:

(1) The personnel cost of managing a commodity at a given facility (excluding command/support and overhead personnel),

(2) The ADP cost of managing a commodity at a given facility,

(3) The voice communications cost of managing a commodity at a given facility, and

(4) The moving costs of relocating a commodity at a given facility (including costs to move, terminate, hire, and train personnel, cost of additional voice communications, and cost of moving equipment).

The assignment of a commodity to a given facility can be accomplished in one of two ways. First, it can be a yes-or-no situation, i.e., the problem assignment variable is a zero-one variable, zero if the commodity is not assigned to the facility, and one if it is assigned to the facility. In this case, the assignment is an integer variable bounded by one. Second, a commodity can be split between facilities with the personnel, ADP, and communications requirement prorated. In this case, the assignment variable is a continuous variable ranging between zero and one. Due to the nature of the problem, it is possible for the solution set of assignment variables to be the same whether or not these variables are defined as integers or continuous variables.

b. Facility Costs. The term "facility" as used in this analysis refers to a possible location at which a commodity can be managed. The facility costs are the sum across the facilities of the problem facility usage variables times the associated costs. The associated costs are the following:

(1) The utilities/maintenance costs of a facility,

(2) The cost of digital communications,

(3) The cost of overhead personnel (i.e., personnel who are associated with the facility and would be eliminated if the facility were closed), and

(4) The cost to close a facility.

The usage of a particular facility is a yes-or-no situation. The facility usage variable is consequently a zero-one variable, zero if the facility is not used, and one if it is used.

c. Command/Support Costs. The command/support costs are the sum across the facilities of the problem command/support variables times the cost of command/support. The command/support variable is based on a relationship between the number of people charged with supervision or support in an ICP frontline function or area and the number of people in that area. The command/support variable is an integer variable.

d. Costs of ADP Increases. The total cost of all ADP increases is the sum across the facilities of the cost of adding an ADP unit through transfer or new acquisition times the number of ADP units to be added. The number of units is an integer variable.

e. Costs of Communications Increases. The costs of communications increases in the digital area are developed in a manner similar to the costs of ADP increases.

f. Costs of Facilities Space Increases. The costs of facilities space increases are also developed in a manner similar to the costs of ADP increases.

2. Constraints. The constraints of the problem serve to define problem variables and to set the magnitude of command/support and increases in ADP, digital communications, and administrative space.

a. Mission Constraint. A commodity can only be assigned to one facility. This is equivalent to saying that the sum of the assignment variables for a commodity must equal one.

b. Facility Usage Constraint. A commodity can only be assigned to a facility which is open. This can be translated into a constraint which states that the sum of commodity assignments at a facility must be less than or equal to the maximum number of commodities times the facility usage variable. This constraint does not allow the facility to be closed while a commodity is assigned to it, i.e., a positive number can not be less than or equal to zero.

c. Facility Space Constraint. At a facility, the space, which is utilized in commodity management, ADP, and command/support, must be less than or equal to the amount of space available or which can be made available.

d. ADP Constraint. The ADP utilized in managing the commodities assigned to a facility must be less than or equal to the ADP currently available or that which can be made available at the facility.

e. Communication Constraint. The digital communications capacity required to manage the commodities assigned to a facility must be less than or equal to the amount of communication currently available and that which can be made available at the facility.

f. Pipe Constraint. The total number of digital communications pipes at any facility can not exceed a maximum number.

g. ADP Transfer Constraint. The total number of ADP units which can be transferred can not exceed the number of owned ADP units available from closed facilities.

h. Number of Facilities Constraint. This is an optional constraint which requires that the number of open facilities be equal to a certain number. This constraint permits analysis of costs for varying numbers of ICPs.

B. Mathematical Statement of Problem

Define:

i = Number of facility

j = Number of commodity

k = Number of functional area

s_i = Number of ADP units purchased for facility i

t_i = Number of ADP units transferred to facility i

u_i = Number of space units built at facility i

v_{ki} = Amount of command/support at facility i in area k

w_i = Number of digital communications pipes installed at facility i

x_i = Number of digital communications pipes upgraded at facility i

y_i = Facility i usage indicator

z_{ij} = Assignment indication of commodity j to facility i

a_i = ADP capacity at facility i

adp_{ij} = ADP cost of managing commodity j at facility i

asl = Resale value of ADP unit

b_j = ADP requirement for commodity j

cl = Cost to acquire an ADP unit

c2 = Cost to transfer an ADP unit

cas = Cost to build a square foot of ADP space

cmax = Maximum number of communication pipes possible at any one facility

cp_{jk} = Personnel cost of one person to manage commodity j in area k

csp_k = Command/support cost in area k

dis = Discount factor

$e2400_i$ = Number of 2400 communications pipes at facility i

$e4800_i$ = Number of 4800 communications pipes at facility i

eqt = Square foot cost to move equipment

f_j = Digital communications requirement for commodity j

g1 = Cost to install 4800 communication pipe

g2 = Cost to upgrade 2400 pipe to 4800 pipe

h_j = Cost to hire to relocate commodity j

iad = Time made available by ADP unit

ico = Communications pipe capacity

isp = Administrative space unit

loc_j = Present location of commodity j

n_j = Number of slots which would transfer if commodity j relocated

num = Number of facilities

o_i = Cost to build space unit at facility i

ovh_i = Overhead cost of facility i

own_i = Ownership of ADP units at facility i

p_{jk} = Persons required in area k to manage commodity j

ppl_i = Number of persons per telephone at facility i

q_i = Cost to close facility i

r_{mn} = Fraction of workforce which will move from facility m to facility n

r2400 = Recurring cost of 2400 pipe

r4800 = Recurring cost of 4800 pipe

rsc = Recurring cost of space

rte_{mn} = Fraction of workforce which will terminate with move from facility m to facility n

sad = Space requirement for ADP unit

sc_i = Space capacity of facility i

spc = Command/support space requirement

spd_{ij} = Cost of relocating person managing commodity j to facility i

$spmx_i$ = Maximum space available for renovation at facility

ter_j = Cost to terminate a person managing commodity j

tr_j = Cost to train a new person for commodity j

usp_k = Number of persons covered by a command/support unit in area k

vot_i = One-time cost of installing telephone line at facility i

vrc_i = Recurring cost of telephone line at facility i

Then the IPP can be expressed mathematically as:

$$(1)\quad \text{minimize} \sum_{ij} \left[(adp_{ij} + \sum_{k} cp_{jk} * p_{jk} + G(i,j) * vrc_i) dis + F(i,j)\right] z_{ij}$$

$$+ \sum_{i} \left[dis * O(i) - q_i\right] * y_i$$

$$+ \sum_{ik} \left[dis * (csp_k + rsc * spc) + spc * o_i\right] * v_{ik}$$

$$+ \sum_i \left[(c1 + cas * sad) * s_i + (c2 + cas * sad - as1) * t_i\right]$$

$$+ \sum_i \left[(g1 + dis * r48\emptyset\emptyset) * w_i + dis * g2 * x_i\right]$$

$$+ \sum_i (o_i + dis * rsc) * isp * u_i$$

subject to

$y_i, z_{ij} = \emptyset,1$ for all i, j (or $z_{ij} \varepsilon [0,1]$)

$s_i, t_i, u_i, v_i, w_i, x_i$ integer

(2) $\sum_i z_{ij} = 1$ for all j

(3) $\sum_j z_{ij} \leq j_{max}\, y_i$ for all i, j_{max} = number of commodities

(4) $\sum_j n_j * z_{ij} + sad * (s_i + t_i) + \sum_k spc * v_{ik} \leq sc_i + isp * u_i$ for all i

(5) $\sum_j b_j\, z_{ij} \leq iad\,(a_i + s_i + t_i)$ for all i

(6) $\sum f_j\, z_{ij} \leq ico * \left[\frac{1}{2}\,(e24\emptyset\emptyset_i + x_i) + e48\emptyset\emptyset_i + w_i\right]$ for all i

(7) $e24\emptyset\emptyset_i + e48\emptyset\emptyset_i + w_i \leq cmax$ for all i

(8) $x_i \leq e24\emptyset\emptyset_i$ for all i

(9) $\sum_j p_{jk}\, z_{ij} \leq usp_k\, v_{ik}$ for all i,k

(10) $\sum_i t_i \leq \sum_i (1 - y_i)\, a_i\, own_i$

(11) $\sum_i y_i = num$ (optional)

where

$$
\text{(12) } F(i,j) = \begin{cases} \emptyset, \text{ when } loc_j = i \\ [eqt * isp + r_{mi} * spd_{ij} + (1-r_{mi})(h_j + tr_j) \\ \quad + rtr_{mi} * ter_j] \; n_j + G(i,j) \; vot_i, \\ \quad \text{when } loc_j = m \neq i \end{cases}
$$

$$
\text{(13)} \quad G(i,j) = \text{integer } (n_j/ppl_i)
$$

$$
\text{(14)} \quad O(i) = rsc * sc_i + e24\emptyset\emptyset_i * r24\emptyset\emptyset + e48\emptyset\emptyset_i * r48\emptyset\emptyset + ovh_i
$$

IV. <u>MODEL USAGE</u>

A. <u>Past Usage</u>. The model described herein was used in support of an ICP Economic Analysis. Several problems were encountered with the application of the model.

1. ADP usage could not be related to the items managed at an ICP. Therefore, the ADP requirement for any item group could not be determined. In general, ADP costs were not exact, i.e., they could not be expressed in the format indicated by the model. Consequently, ADP had to be omitted from model runs.

2. Command/support relationships were not developed and hence were not included in the model runs. Not enough data was available in this area for analysis. If the data had been made available, it is doubtful that any reliable relationships could have been identified in the time frames given for the Economic Analysis.

3. Identification of fixed overhead costs versus variable commodity costs was difficult. It was more of an art than a science.

4. The use of standards in space requirements led to some difficulties. At one point, DGSC required additional space units in the baseline scenario.

5. In general, the IBM Mathematical Programming System Extended (MPSX), which was used to solve the model, was a good package. However, the input format makes the construction of a matrix generator a necessity.

B. Present Usage. At the present time, the model is being expanded as part of a comprehensive ICP study. The following elements have been introduced into the model:

1. Time. Timing of ICP realignment is included in the model. Program variables are now subscripted by time.

2. Disruption. Realignment is being constrained to certain levels of disruption. This is an attempt to introduce performance in the model.

3. MILCON Funding. New building and/or renovation is subject to a budgetary constraint.

4. Cost Refinement. In anticipation of increased availability of data, costs are refined. That is, they are being subscripted to a greater extent. In place of system averages, detailed costs will be considered.

These represent the major changes to the model. Undoubtedly, other changes will be introduced as study continues in the ICP area. The final goal is a model which will consider all major items of ICP alignment.

C. Future Usage. Besides future ICP planning, the model could be revised to study other DLA activities. The integer programming approach lends itself to facilities planning. The number of DCASRS, depots, disposal sites, etc. could be analyzed using an integer programming model. In fact, work has been done in some of these areas but has not been formalized.

V. SUMMARY

The following points can be made:

A. The use of integer programming in facilities planning is not new.

B. A DLA ICP model has been formulated.

C. The model is being expanded as part of a comprehensive ICP review.

A COMMON DENOMINATOR IN PROCUREMENT QUALITY ASSURANCE

by Melvin A. Mallory

CHART 1

Good morning - Ladies and Gentlemen! This morning I would like to describe for you a common denominator in procurement quality assurance which is becoming very significant in DCASR Chicago.

CHART 2

This chart shows the coefficient of correlation of the various workload indicators to QAR manpower at all of the levels of our organization where QA management decisions must be made. You can see there are indicators which show a high degree of correlation at the CAS level (shipments and visits for example). At the region level where PERS is applied - shipments havethe highest correlation with product units inspected coming in a close second. But at the QA branch/section level where LAPERS is supposed to work and at the facility level where the product quality decisions are made the coefficients of correlation diminish rapidly to a relatively insignificant level. Even our primary budget indicator "QA Contracts on Hand" shows a relatively low level of correlation to QAR manpower at all levels of management. There is only one indicator which we have named the "Weighted Composite Observation" which has a high degree of correlation to QAR manpower at all management levels of our organization. This is the common denomination I will describe for you today. I will show you: What it is; why it is that; and how it relates to the complexity of the product we assess and the criticality of the requirements we inspect. I will also show how it can be used to assess the effectiveness of our efforts, to gage the direction we must move to become more proficient, and when combined with forecasted missions, describe future needs for QA manpower. You will have to agree, if it can play a part in doing all of this, it is properly titled "A Common Denominator." This is a big order and I have a lot to cover in the next 30 minutes. If I go too fast for you or if you have any short questions, please feel free to pop right in and ask them. If your questions are philosophical or would lead to lengthy discussions please hold them back until after the presentation. I would be willing to meet with any of you later today to discuss the material shown. I can best describe the "Weighted Composite Observation" by telling you about the operations research efforts we call normal quality analysis. A report on normal quality analysis was first made in February 1971. Some of the material you will see comes from that report. You will also see what has transpired since then. I have a limited number of copies of both the 1971 report and today's presentation with me. Additional copies may be obtained by writing to me in Chicago.

DCASR, CHICAGO

A
COMMON DENOMINATOR
IN
PROCUREMENT QUALITY ASSURANCE

JULY 1977

CHART 1

CORRELATION OF QA WORKLOAD AND QAR MANPOWER

INDICATOR	CAS	REGION	QA BRANCH/SECTION	RESIDENT FACILITIES
$ VALUE NEW BUSINESS	.235	.159	.214	.487
$ VALUE SHIPPED	.668	.829	.255	.667
UNDELIVERED $ BALANCE	.354	.868	.268	.720
SHIPMENTS	.928	.906	.316	.475
VISITS	.940	.682	.289	.145
CONTRACTS RECEIVED	NA	.143	.163	.365
CONTRACTS ON HAND	.004	.388	.184	.450
CONTRACTS CLOSED	NA	.568	.144	.420
PRODUCT UNITS INSPECTED	-.050	.897	.679	.337
DEFECTIVE PRODUCT UNITS	.209	.889	.454	.291
WEIGHTED COMPOSITE CHARACTERISTICS	.877*	.892*	.857*	.925*

CHART 2

CHART 3

The original research eminated from the 1964 issue of ASPR - 14, which remains essentially unchanged. I am sure all of you are familiar with it, but I would like to emphasize one point in ASPR - 14 - 403 which requires the CAO to use contractor generated data to adjust the amount of Government PQA to a minimum consistent with proper assurance that supplies or services accepted conform to contract quality requirements.

CHART 4

Here you can see a comparison of the early product inspection observation work counts to QAR manpower. You can also see that at the branch/section level a relatively strong correlation exists, but falls apart at the plant level. The 1 February report contains several examples of this chart effort.

CHART 5

There was a strong consensus that the variation in individual facilities was because of the differences in the type of commodities they produce. So in January 1968 we plotted the product inspection work effort data of all resident facilities while grouping them in commodity groups. Here you can see that commodity groups 0, 1 and 3 generally followed the overall estimating line. Commodity 6 which was nuclear effort had a completely different estimating line. Commodity 8 (aircraft & weapons) closely follows the nuclear line except for one company - Arnolt Co. The Arnolt inspection effort is best described by a point just below the overall estimating line but 5 times the length of the line on the chart.

CHART 6

In the electrical - electronics commodity the same is true. It could even be argued that there are 3 separate and independent lines for this commodity.

CHART 7

The scatter diagram for the mechanical commodities is just that - a scatter diagram. 3 and possibly 4 lines seem evident. In every case there appears to be those maverick plants which tend to follow the overall estimating line.

CHART 8

In the munitions commodity we have a completely different story. Almost all of the plants follow an estimating line which is similar to or just below the overall estimating line. What is the difference? Why does it take so much more manpower to make a product inspection observation in the electrical, nuclear and aircraft commodities than it does in the munitions commodities? The answer to that question should be quite

14-102 Responsibilities of the Contractor.
(a) The contractor is responsible for carrying out his obligations as set forth in the terms and conditions of the contract and in the applicable specifications. Most Department of Defense contracts include, or reference, standard requirements, such as those in general provisions, special clauses for an inspection system or quality program, and performance and product specification requirements. The contractor is responsible for controlling product quality and for offering to the Government for acceptance only those supplies and services that conform to contract requirements and, when required, for maintaining and furnishing substantiating evidence of this conformance.

14-103 Responsibilities of the Government. The Government shall determine the type and extent of Government procurement quality assurance actions required, based upon the particular procurement. These actions may include:

(i) inspection of supplies and services;
(ii) review of the contractor's inspection system, quality program, or of any other means employed by the contractor to control quality and to comply with contract requirements;
(iii) maintenance of Government records to reflect actions, deficiencies, and corrective measures; and
(iv) review and evaluation of quality information, including reports from the user, to initiate required corrective actions or to adjust Government procurement quality assurance actions.

14-403 Implementation.
(a) Determination of conformance to contract quality requirements shall be made on the basis of objective evidence of quality. In determining the acceptability of supplies or services, the contract administration office shall make optimum use of quality data generated by contractors. To the extent that contractor quality data are available and reliable, as determined by the contract administration office, such data shall be used to adjust the amount of Government procurement quality assurance to a minimum consistent with proper assurance that the supplies or services accepted conform to contract quality requirements.

14-405 Quality Evaluation Data. The contract administration office shall establish a system providing as a minimum for the collection, evaluation and, use of quality data developed (1) by the contractor during manufacture and (2) by the Government through procurement quality assurance actions and reports by users during initial use phase, where available. The objectives of the system are to:
(1) provide a foundation for technical actions aimed at maintaining and making needed improvements in the quality characteristics of both current and future products (subject to military requirements and cost considerations);
(ii) upgrade the methods and practices used to assure quality during manufacture, delivery, and use of the item;

DCASR CHICAGO

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

SEPTEMBER 1967

Q 66

PLOTTING SYMBOLS

- ● CAS
- ★ REGION
- ⊟ DISTRICT
- ⊙ OFFICE
- ▲ DIVISION
- ✱ BRANCH
- • QAR

$Yc = a \times b\ X$
$a = .248$
$b = .009072$

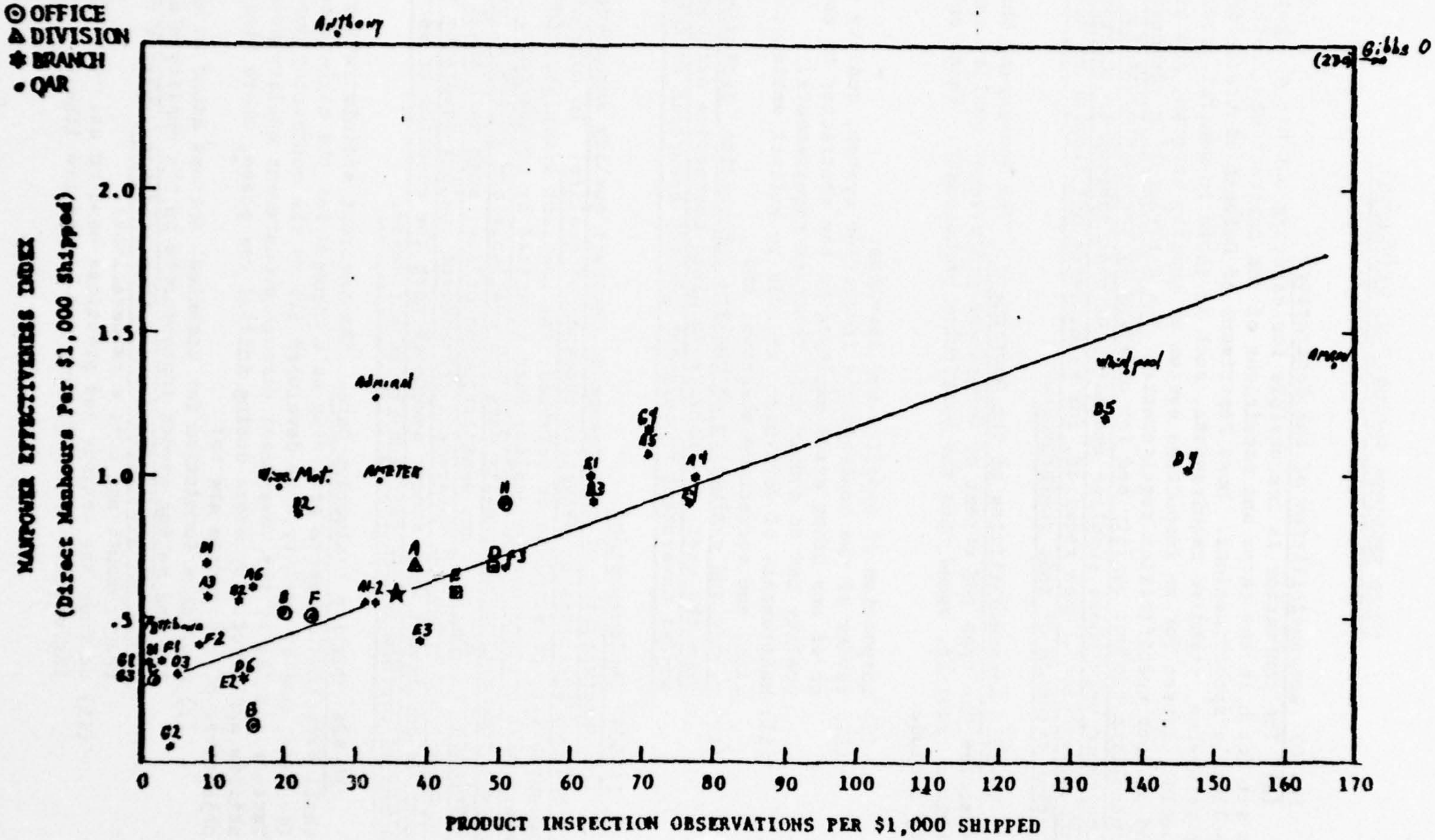


CHART 4

Q 62

JANUARY 1968

DCASR CHICAGO

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

Resident Contractor Facilities

Commodities: 0, 1, 2, 3, 6, 8 & 9

$Yc = a + bx$

a = .2526

b = .009624

s = .0912

r = .9861

PLOTTING SYMBOLS

- ● CAS
- ★ REGION
- ⊟ DISTRICT
- ⊙ OFFICE
- △ DIVISION
- ✱ BRANCH
- • QAR

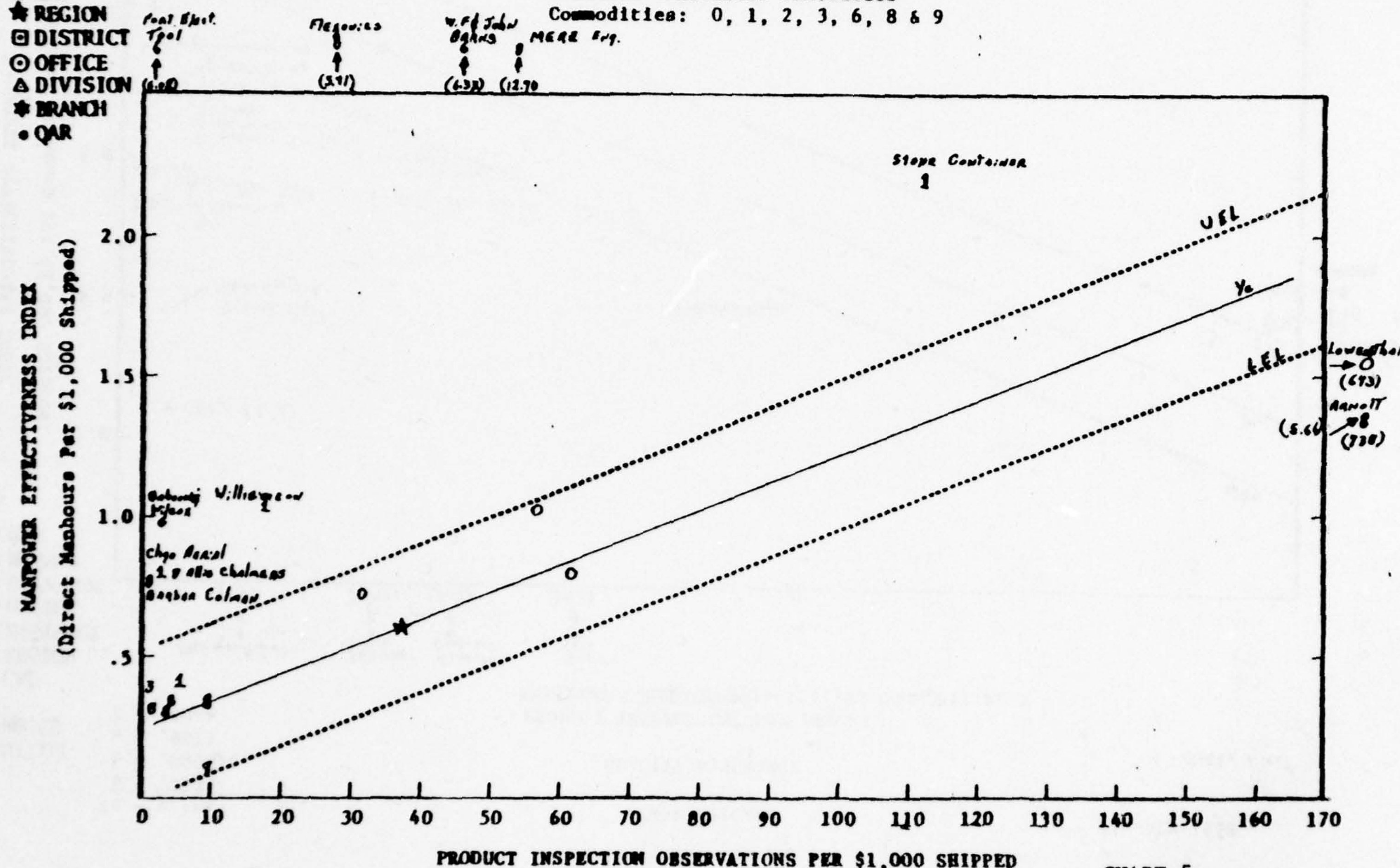


CHART 5

Q 62a

DCASR CHICAGO

JANUARY 1968

QUALITY ASSURANCE

4 - Gibbs Elect.

PRODUCT INSPECTION WORK EFFORT
RESIDENT CONTRACTOR FACILITIES COMMODITIES 4

$Yc = a + bx$
$a = .2526$
$b = .009624$
$s = .0912$
$r = .9861$

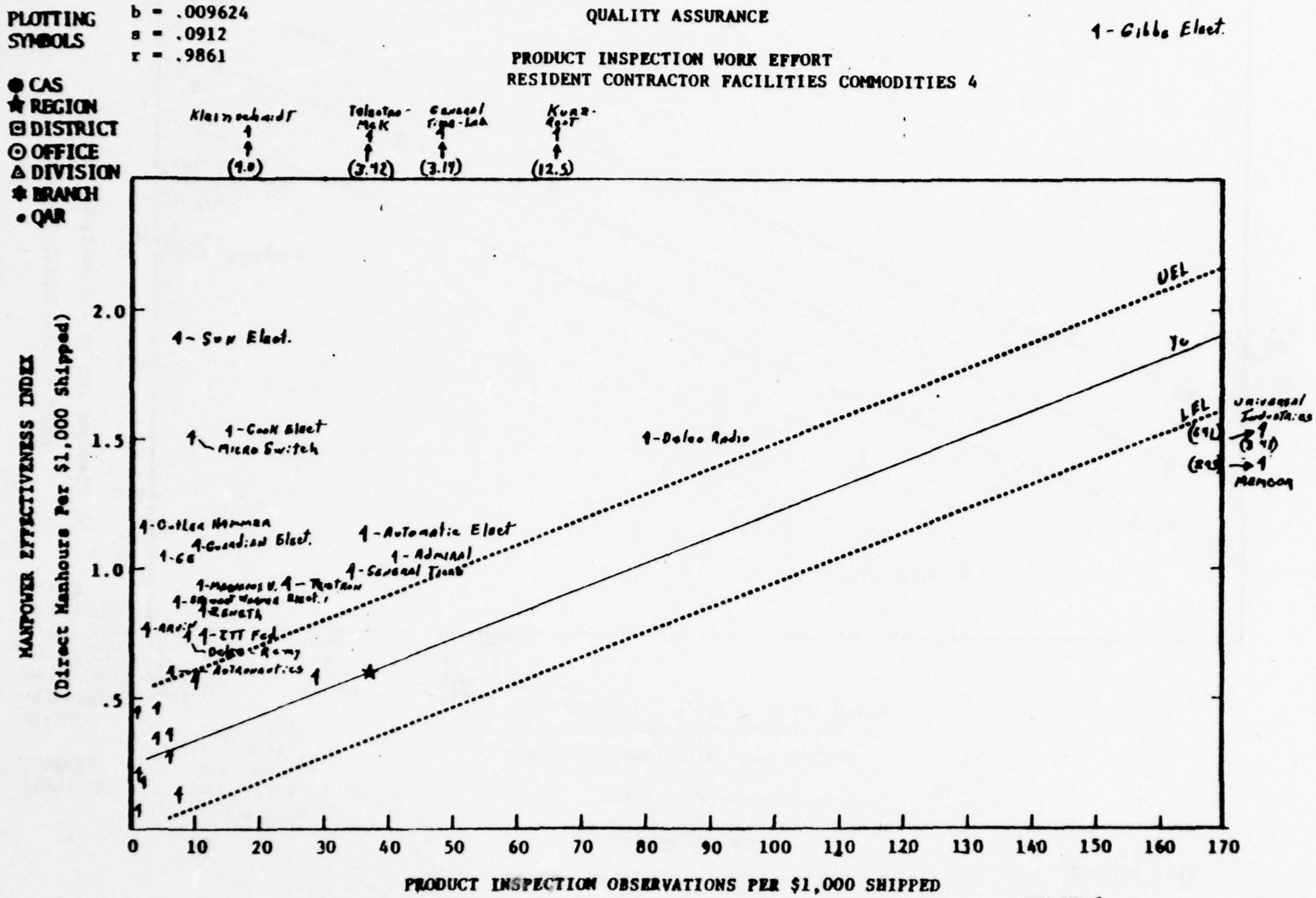


CHART 6

Q 62b

DCASR CHICAGO

JANUARY 1968

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

RESIDENT CONTRACTOR FACILITIES COMMODITY 5

PLOTTING SYMBOLS

- ● CAS
- ★ REGION
- ⊡ DISTRICT
- ⊙ OFFICE
- ▲ DIVISION
- ✱ BRANCH
- • QAR

$Yc = a + bx$
$a = .2526$
$b = .009624$
$s = .0912$
$r = .9861$

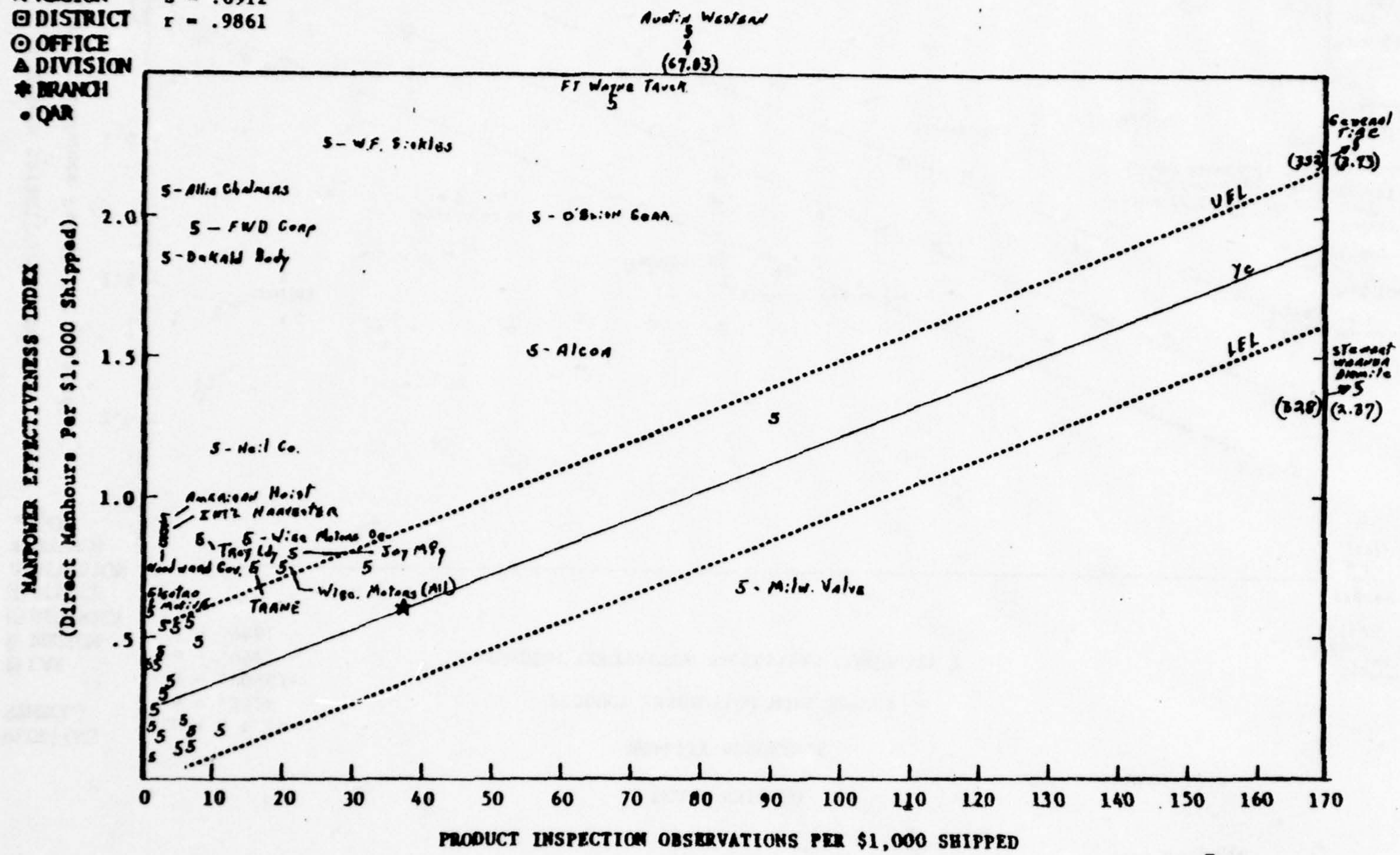


CHART 7

Q 62c

DCASR CHICAGO

JANUARY 1968

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

RESIDENT CONTRACTOR FACILITIES COMMODITY 7

PLOTTING SYMBOLS

- ● CAS
- ★ REGION
- ⊡ DISTRICT
- ⊙ OFFICE
- △ DIVISION
- ✱ BRANCH
- • QAR

$Yc = a + bx$
$a = .2526$
$b = .009624$
$s = .0912$
$r = .9861$

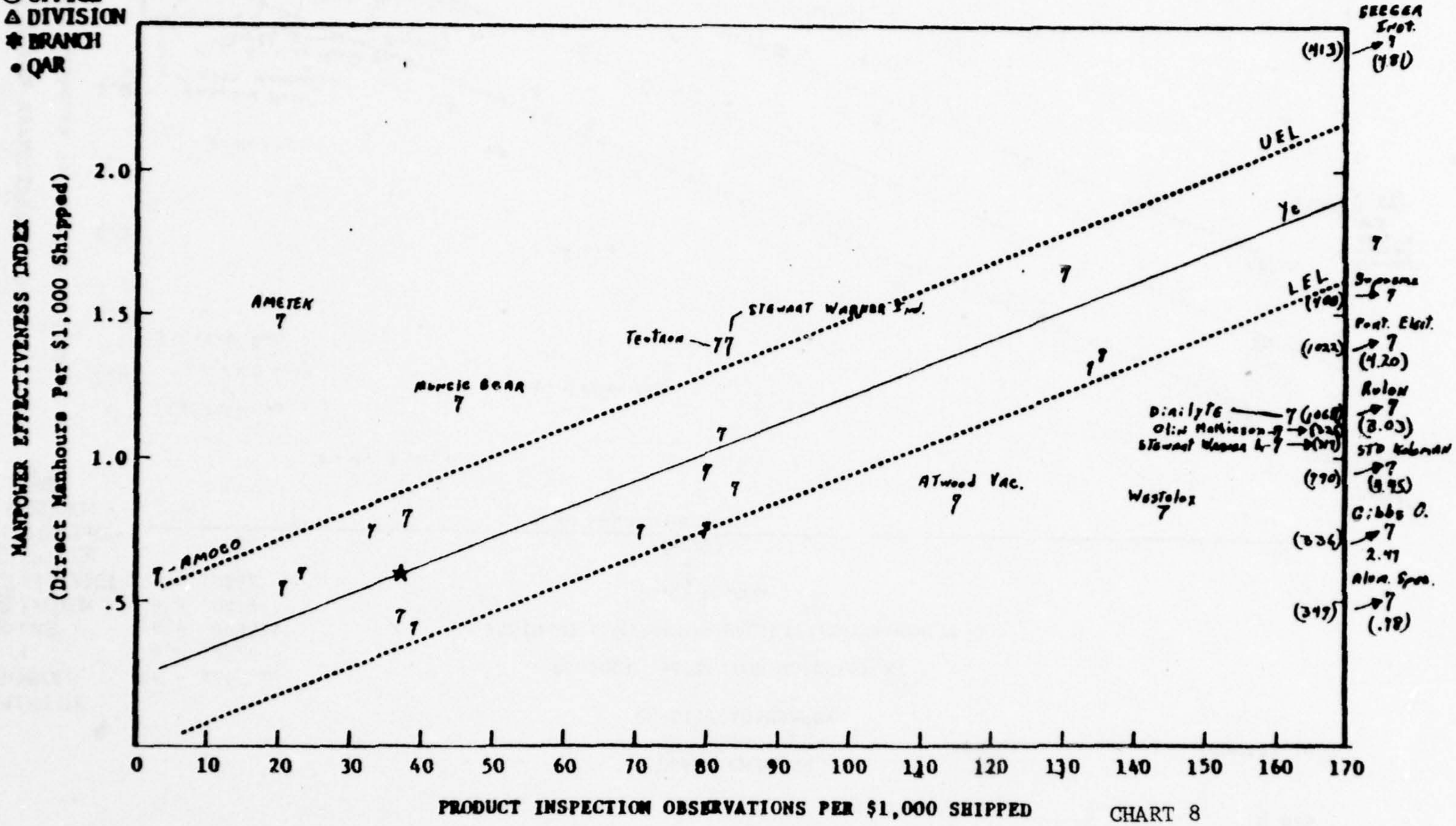


CHART 8

evident - because the munition commodity is far more precise in describing what a quality requirement is. You are not only told what to measure and where to measure it, but how many times and in many cases the serial number of the gage to use. In the mechanical commodity, a typical requirement would be: The concentricity of a 10' 3" diameter shaft must be ± .003". Where? How many places? What instruments to use? - were (and still are) questions left up to the QAR to solve. I used to inspect receivers/transmitters to a requirement for receiver sensitivity of 6 decibels at 5 micro volt signal input. This unit operated on 1450 different fequencies each crystal controlled by a combination of 5 out of 41 crystals. What was a product inspection observation? A complete test for sensitivity at all 1450 frequencies or at both ends of the band and in the middle? From 1968 until the fall of 1970 this was the subject of much conversation between QA specialists. The 1971 report contains some letters from CAS trying to standardize the definition of an observation. It was an impossible job.

CHART 9

In October 1970 the scatter diagram of our product inspections work effort looked like this. It looked like there were two schools of thought on what an observation was and variations in the opinions of how much time it should take to do one, to the magnitude of 10 to 1. (Note the positions of the mechanical branches D1, A22, A42 and the munition branches A12 and E1.) The real problem for the progressive QA manager was to find a way to make this data meaningful without establishing reporting procedures so complicated that no one could live with them. This was the real goal that was established for the operations research project on normal quality analysis.

CHART 10

Early in the days of PERS (1967) there was a technique defined which recognized differences in work based on the amount of time required to accomplish it. It was called the "composite work unit concept." Here you can see that various amounts of different types of work can be compared and summarized simply by establishing a relative weighting factor for each type and multiplying the actual count by the weighting factor. Fine! Let us do it with the product inspection observation.

CHART 11

This is a frequency distribution histogram of the manhours expended per observation by QARs in individual contractor facilities. Fantastic!!! - - We had about 15 facilities where the time to make an observation was less than 1.8 seconds! We also had 3 facilities (environmental testing laboratories where the time required to make an observation was 5-15 hours. What should the basic weighting value be? - - - As I indicated I am an old electronics man and I have looked at histograms like this many times as power spectrum characteristics of transmitters better known to many as signature characteristics. These histograms are so unique that no two transmitters have the same characteristics. The characteristics are established by the precise dimensions of the tuned circuits of the transmitter and are identified by the harmonic content of the spurious frequencies. My

PLOTTING SYMBOLS

★ REGION
⊡ DISTRICT
⊙ OFFICE
△ DIVISION
✱ BRANCH
● QAR

QUALITY ASSURANCE
PRODUCT INSPECTION WORK EFFORT

Q 306 1

OCTOBER 1970

$y_c = a + bx$
$a = .2612$
$b = .01202$
$S_{yx} = .2112$

DCASR CHICAGO

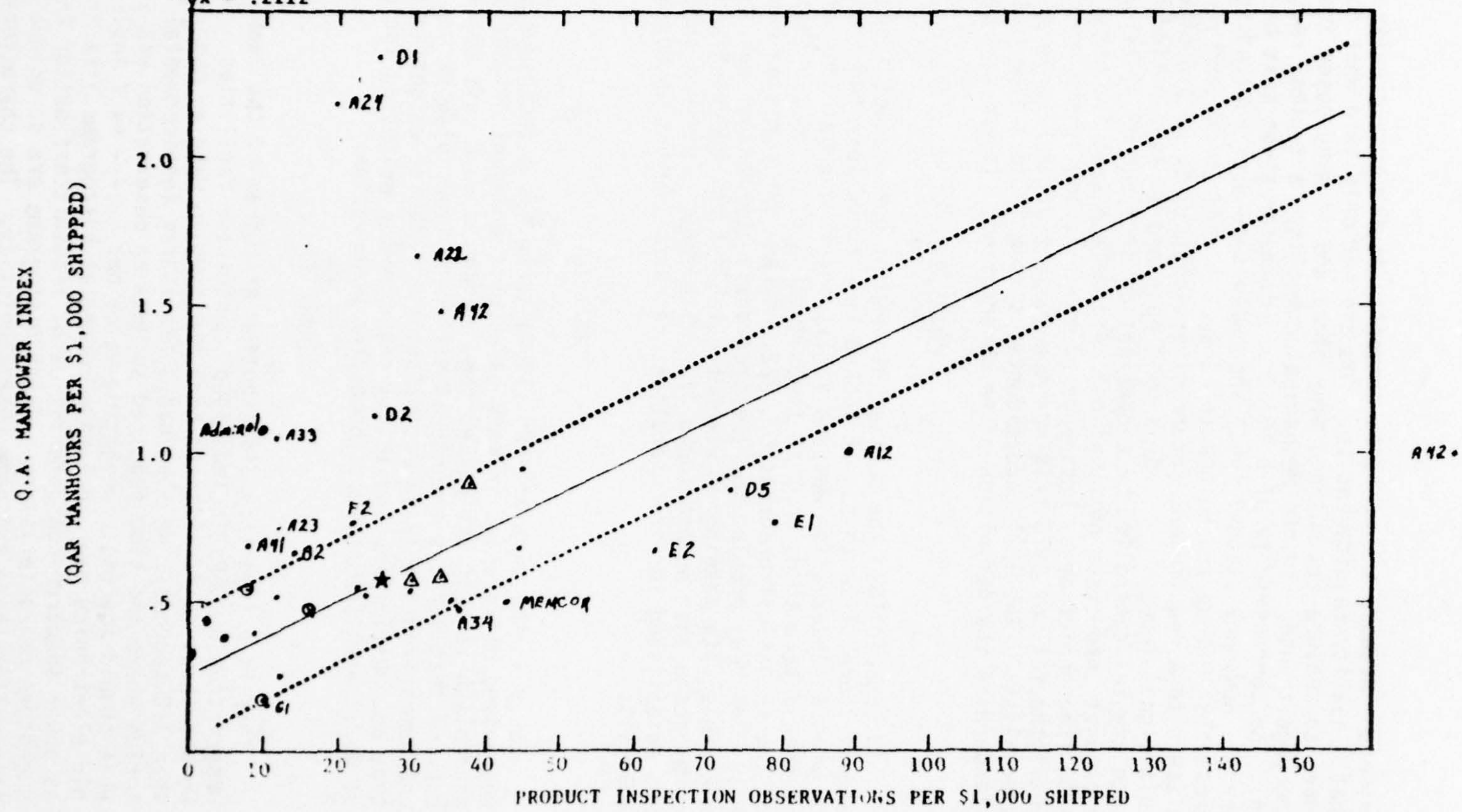


CHART 9

COMPOSITE WORK UNIT CONCEPT

WORK PRODUCT	MANHOURS PER UNIT	RELATIVE WEIGHTS	ACTUAL WORKLOAD	WEIGHTED WORKLOAD
A	1.5	3.0	200	600
B	.5	1.0	100	100
C	2.0	4.0	300	1200
				1900

CHART 10

DCASR CHICAGO JAN-MAR 1971

MANHOURS PER PRODUCT INSPECTION OBSERVATION

REPORTING CHARACTERISTICS

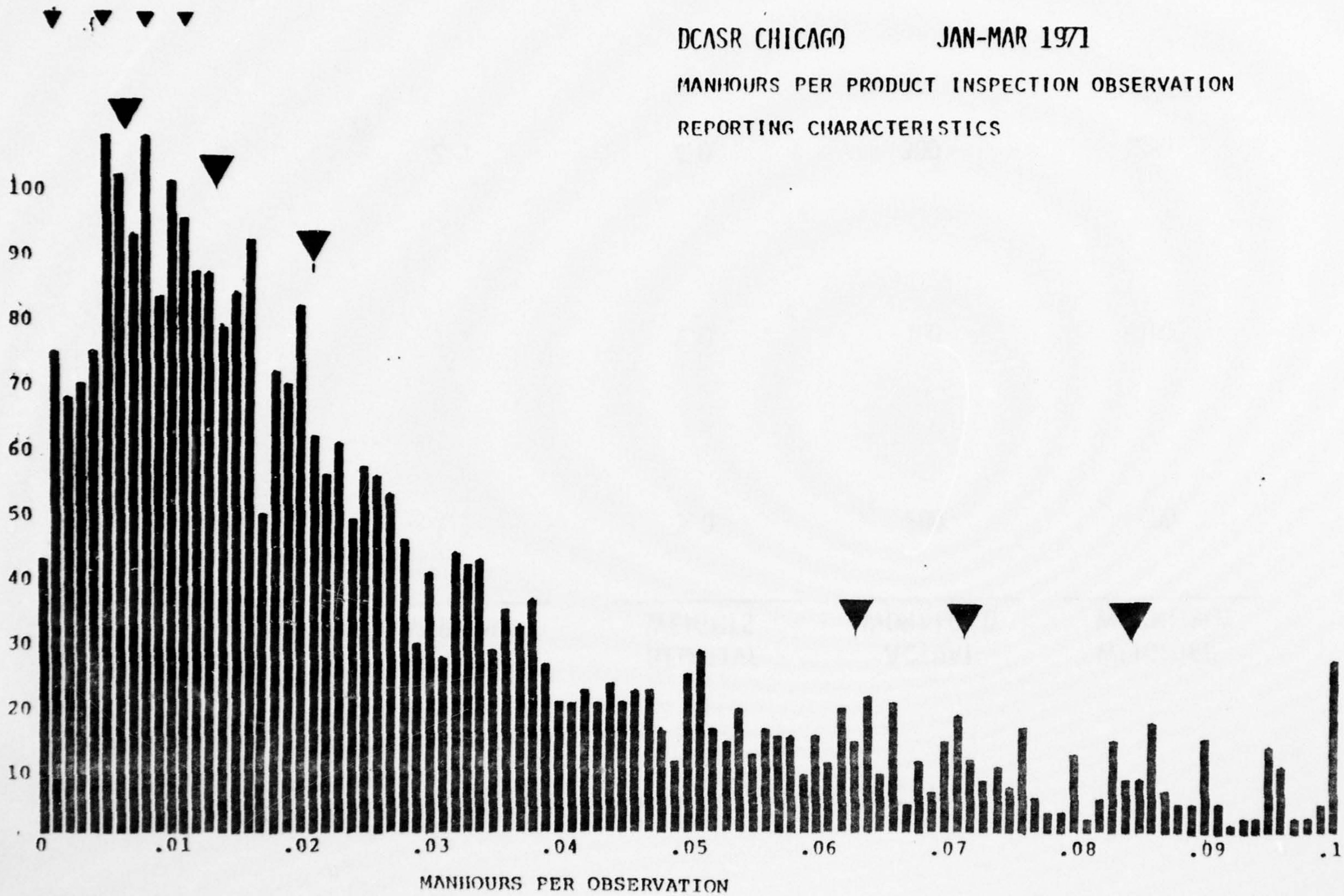


CHART 11

goodness - did I say that? No matter - what it all boils down to is a tendency for a happening to occur once - twice - thrice - etc. Let's look again at this histogram with that view. As you can see, there are groupings of the times into patterns that appear to repeat themselves forming lobes. They can be identified by the low rate of occurrence between them. One seems to occur at .017 and repeats at .029 or .031, repeats again at .049 and .067, then becomes obscure. These do not appear to be exact multiples of the basic .017. Another very strong lobe pattern occurs at .007, repeats at .014 and .021, becomes a little obscure at .035, .042 and .049, but comes back very strong at .063, .070, and .084. You can readily see that these values are all multiples of the basic value of .007. Why should this happen? Think about it -- if .007 manhours (25.2 seconds) represented the time required to make one discrete measurement, then .014 or 50.4 seconds would represent the time required to make two measurements etc. It then goes without saying that when a QAR reports that he took .084 manhours to inspect a sample that he is telling us that the inspection consisted of 12 discrete measurements. That's really saying a lot. Let's look again at the chart. What are those single spikes that stick up through the chart? Three or four of them appear in each increment of .007. They basically say that there is an inspection effort that takes 1/3 to 1/4 of the time it takes to measure something. What is it? Why visual - mechanical inspections, of course. What should the value of the weighting factor for the weighted composite observations be? Should it be based on the gaged and measured characteristics or on the visual - mechanical characteristics? The decision was to base the weighting factors on the basic gaged-measured characteristics of .007 manhours or 25.2 seconds. Now let's go back to that October 1970 data. Divide manhours required to make a product inspection observation by .007, and multiply the result by the number of observations made.

CHART 12

This is the result. Fantastic! It would appear that all QARs expend manpower at a rate directly proportional to the number of characteristics they inspect. (Not the movement of branches D1, A22, A42, while there was relative no movement of the munitions branches A12 and E1.)

CHART 13

In January 1971 I had the opportunity to do a composite product inspection observation analysis on DCASR St. Louis. As you can see, almost all of the commodities in that region follow the same estimating line as in Chicago.

CHART 14

As a matter of fact, if you were to construct a scatter diagram of all of the CAS product inspection work effort and exclude any reference to the $ value of material shipped, it would look like this: Please note that in order to make this chart small enough to view we have used log-log graph paper. If this chart were placed on linear graph paper and the scale

PLOTTING SYMBOLS

★ REGION
⊡ DISTRICT
⊙ OFFICE
△ DIVISION
∗ BRANCH
● QAR

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

Q 306-2

COMPOSITE OBSERVATION COUNT

OCTOBER 1970

DCASR CHICAGO

$y_c = a + bx$
$a = .02368$
$b = .01342$
$S_{yx} = .1362$

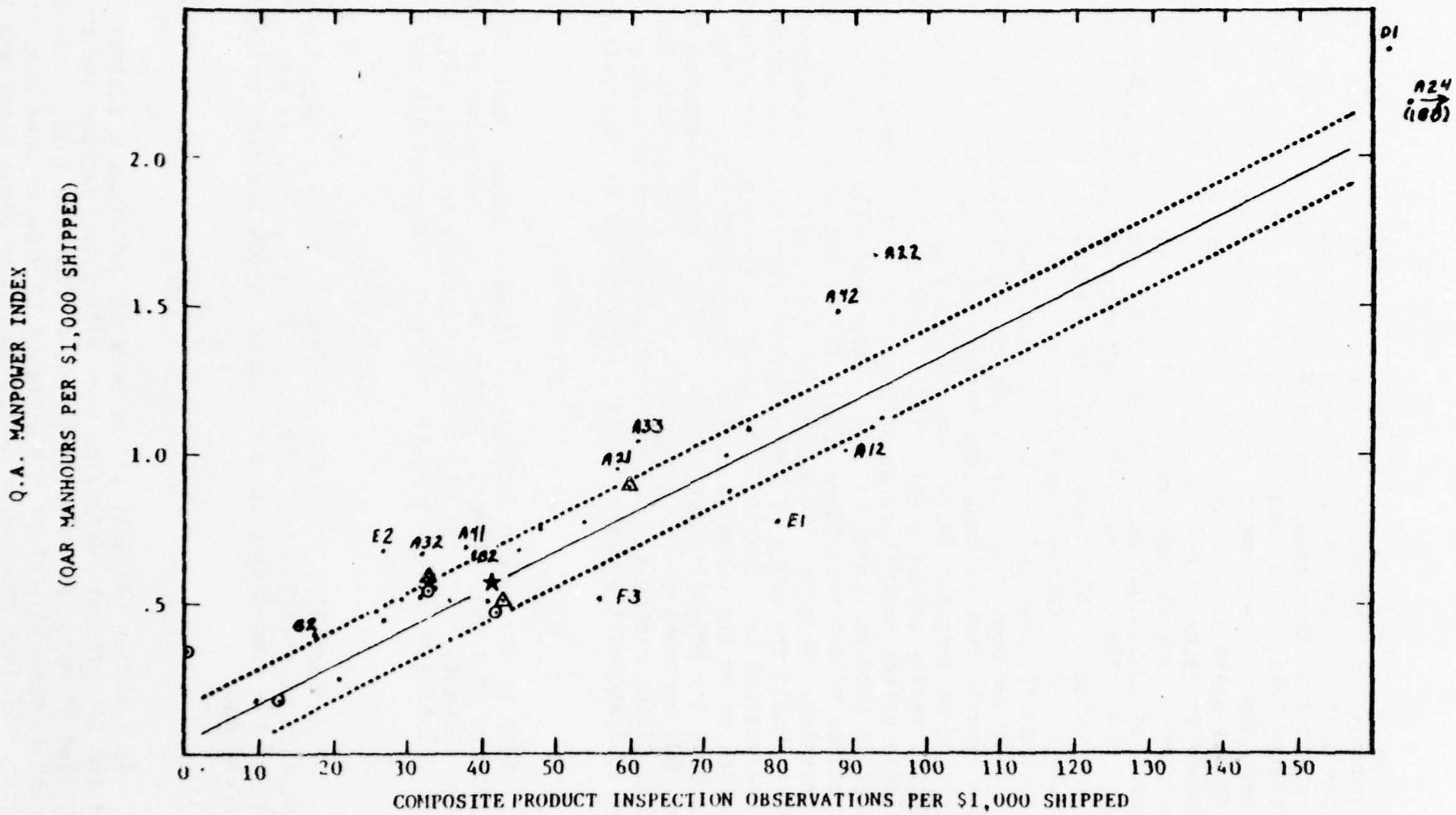


CHART 12

QUALITY ASSURANCE

PRODUCT INSPECTION WORK EFFORT

COMPOSITE PIT OBSERVATION

COMMODITY SUMMARY

July-Dec 1970

DCASR ST LOUIS

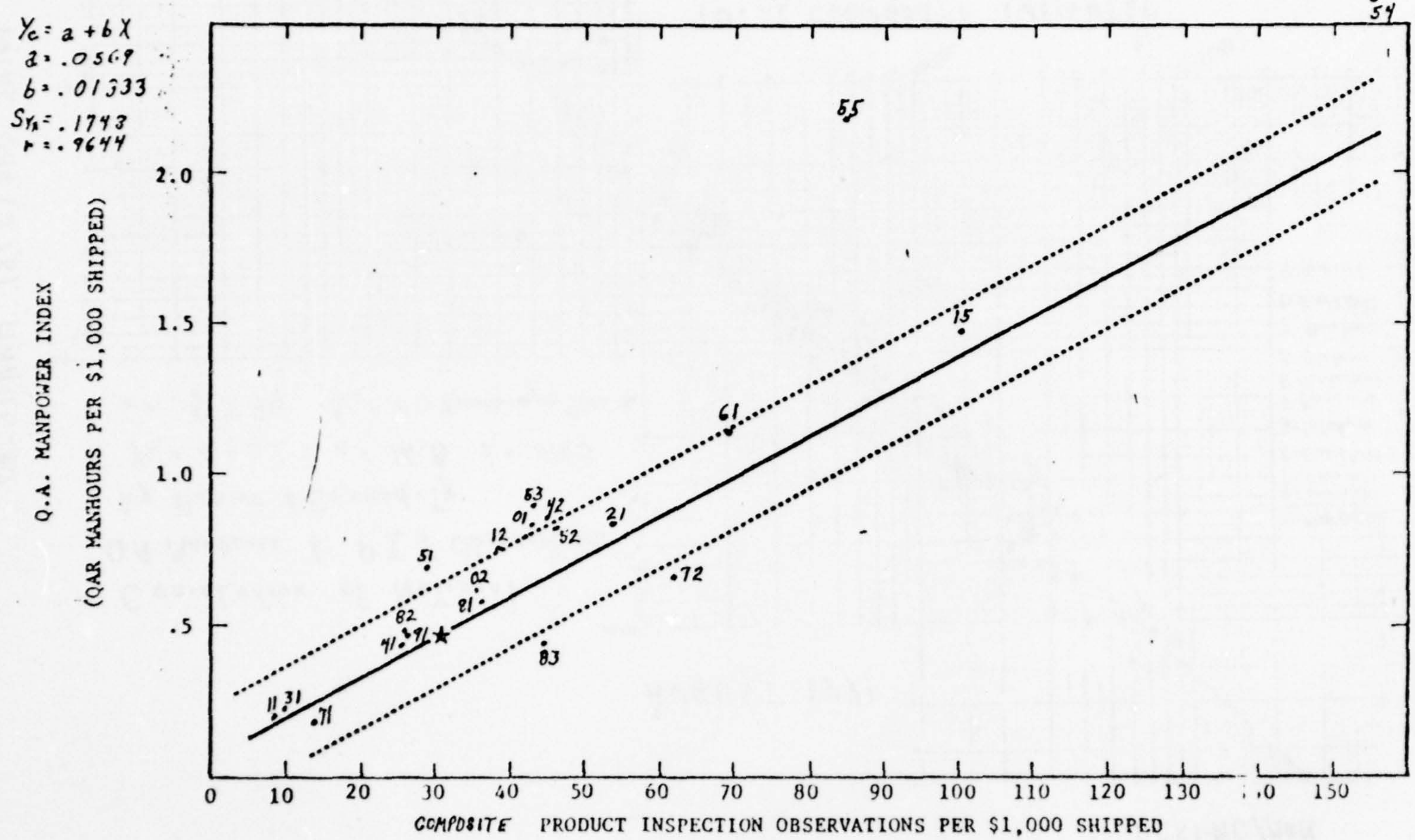
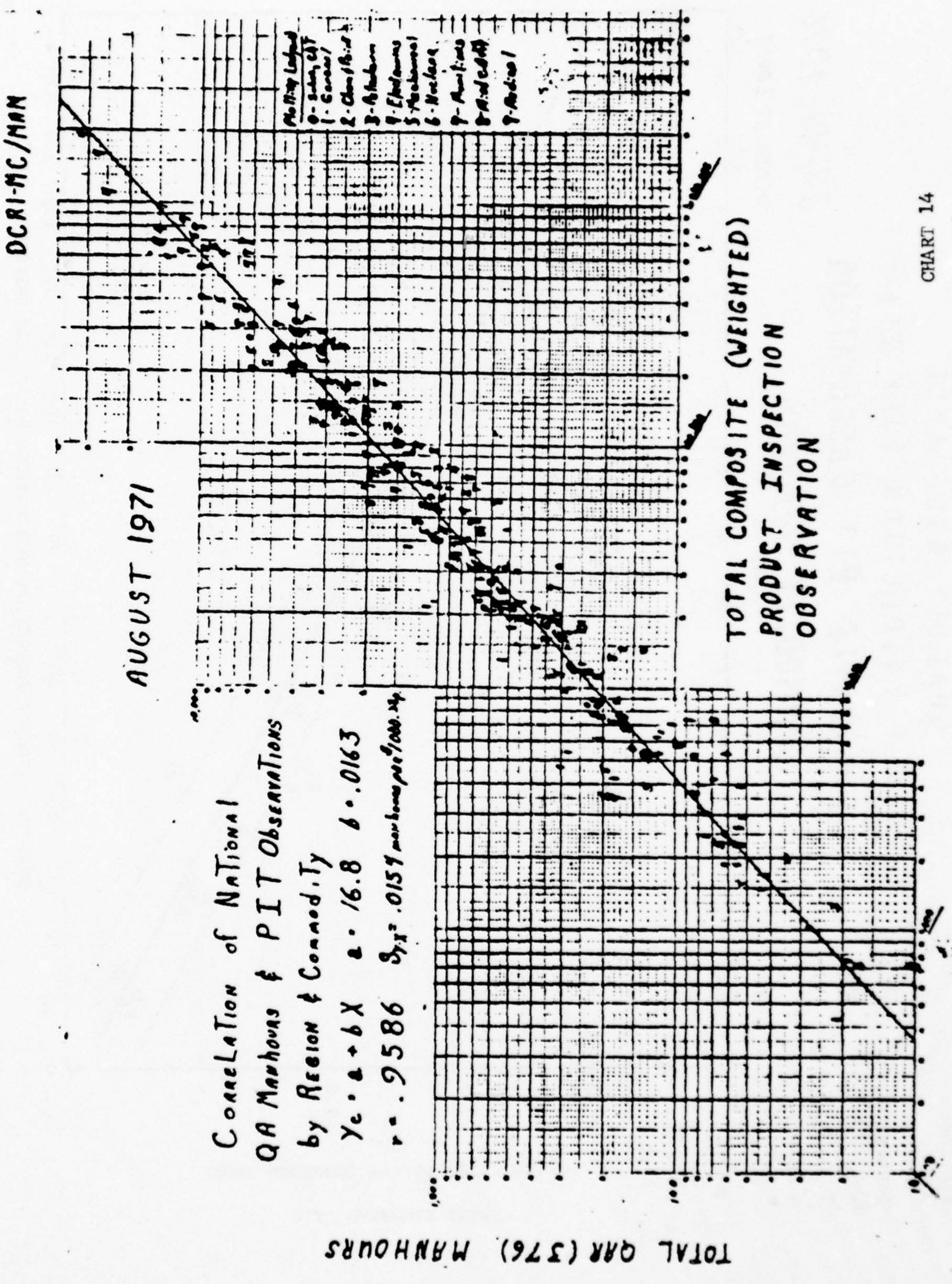


CHART 13



DCRI-MC/MAN
AUGUST 1971
Correlation of National
QA Manhours & PIT Observations
by Region & Commodity
Yc = a + bX a = 16.8 b = .0163
r = .9586
TOTAL COMPOSITE (WEIGHTED)
PRODUCT INSPECTION
OBSERVATION
TOTAL QAR (376) MANHOURS

CHART 14

calibrated to the same increment as the first two inches of this graph, the line would be 1192 ft. long and 766 ft. high at the farthest point, and it still would be a straight line. It is a little staggering to see that the expenditure of almost 20 manhours on just about 700 observations on nuclear items in Dallas, Texas is in almost the same proportion at the expenditure of almost 32,000 manhours and 2 million observations on electronics equipment in New York and all QARs are working the same way. If you look closely at the chart, you will see that the electronics and mechanical commodities generally
appear above the line while munitions appear below the line. This additional manpower requirement can only be interpreted to be the effort needed to identify, define and describe the detailed inspection procedures.

Now, let me ask - what does this chart really tell us? - - - It tells us that when a QAR decides that an inspection must be made, the manpower required to make it is directly proportional to the type of inspection and the number of discrete observations needed. That is all that it tells us. Nothing more! It does not tell us if the inspection was really needed. It does not tell if the inspection level has been adjusted to a minimum consistent with ASPR 14-403. It does not tell us if the quality conforms to contract quality requirements. It does do one thing for us, however. It establishes a common base line (a common denominator if you will) by which all of these things can be determined.

The most important issue for example is the quality of material being offered for acceptance. To examine this issue we must determine what quality requirements are established in the contract.

CHART 15

Most quality requirements established in contracts and contract specificiations are defined in terms of the acceptable quality level. (Note: Read the definition with emphasis on the words "can be considered satisfactory as a process average.) To be consistent with ASPR 14-403, QARs should be using contractors' data to accept material when the contractors' process average is less than the AQL and the contractors' data is reliable. Likewise, the QAR should be inspecting material where the contractors' process average is greater than the AQL or is unrealiable. Simple! - Compare the two process averages to the AQL and to each other. Woops! That's a lot of data and not all of it is available. First, AQLs are specific requirements placed on individual tests, parts, assemblies and maybe final assemblies. Second, none of the contractors' data is contained in our management data, the QA activity report. Third, the QARs product inspection data yields only one process average which is a composite of all the inspection results for the month. What we need is a composite AQL. We know the composite work count describes the complexity of the QAR's inspection effort. Would it be possible to estimate a composite AQL (or if you will a normal quality level for the QARs effort based on complexity)? Let's examine once again the AQL and how it is established.

ACCEPTABLE QUALITY LEVEL (AQL) FROM MIL-STD-105D

PARAGRAPH 4.2 DEFINITION: THE AQL IS THE MAXIMUM PERCENT DEFECTIVE (OR THE MAXIMUM NUMBER OF DEFECTS PER HUNDRED UNITS) THAT, FOR PURPOSES OF SAMPLING INSPECTION, CAN BE CONSIDERED SATISFACTORY AS A PROCESS AVERAGE.

CHART 15

CHART 16

Here you see several AQLs which occur with surprising regularity in contracts and contract specifications. I am sure we have all seen AQLs which are established for individual characteristics and AQLs which have been established for grouped characteristics. All of the statistical quality control text books state that AQLs for grouped characteristics must be higher than for individual characteristics, establishing a natural progression of the AQL, but none define that progression in precise terms. Here you see my estimation of the natural progression of the AQL based on 20 years of inspecting material to those AQLs. This original estimate has proven to be surprisingly close to the real progression. As you can see the estimating formula selected for the composite normal quality level is the same as it should be for Major B characteristics, on the premise that the effect of critical and Major A characteristics would be nullified by the effect of minor characteristics. Naturally any inspection operation which contained a higher than normal mix of critical or Major B characteristics would have to have lower normal quality level in order to properly assess product quality. Until now our QA activity report has not revealed the mix of the criticality of the QARs product inspection findings. Maybe in the future it will. Along these lines I seem to remember some concerted effort to collect information from the Services on the quality of material being received from contractors under DCAS administration. The figure of 14% defective got tossed around a little, but was rapidly discarded because none of the data in our QA activity report showed process averages that high. There are two important points to be made in this respect. (1) Our data is the sum of findings of many discrete inspections on components, sub assemblies and inspection stations; nowhere do we have the accumulation of product quality for complete deliverable contract items, and (2) We do not normally include findings relating to product defectiveness observed while performing concurrent inspection with the contractor. Based on the estimating formula for the normal quality level it would be reasonable to observe 14.7% defective material if the inspection took at least 1 hour to perform. At one time in my career, I was required to test Navy radar switchboard equipment for what they call cross-talk. The complete test took just over one hour. - - - Can you guess what the AQL was? - - - You guessed it! Fifteen defects per hundred units tested.

CHART 17

Since the estimate of the normal quality level is based on a standard formula it can be tabled for ready reference by QA specialists and managers. Better yet, it can be programmed into the computer and provided for each facility listed in the QA activity report.

CHART 18

It is also possible to construct a table of defect action limits so that QARs can determine how contractors' individual process averages compare to individual AQLs without being a math wizard or having access to

DCASR, CHICAGO
DCRI-MC/M. Mallory
15 October 1970

ESTIMATING THE NORMAL QUALITY LEVEL

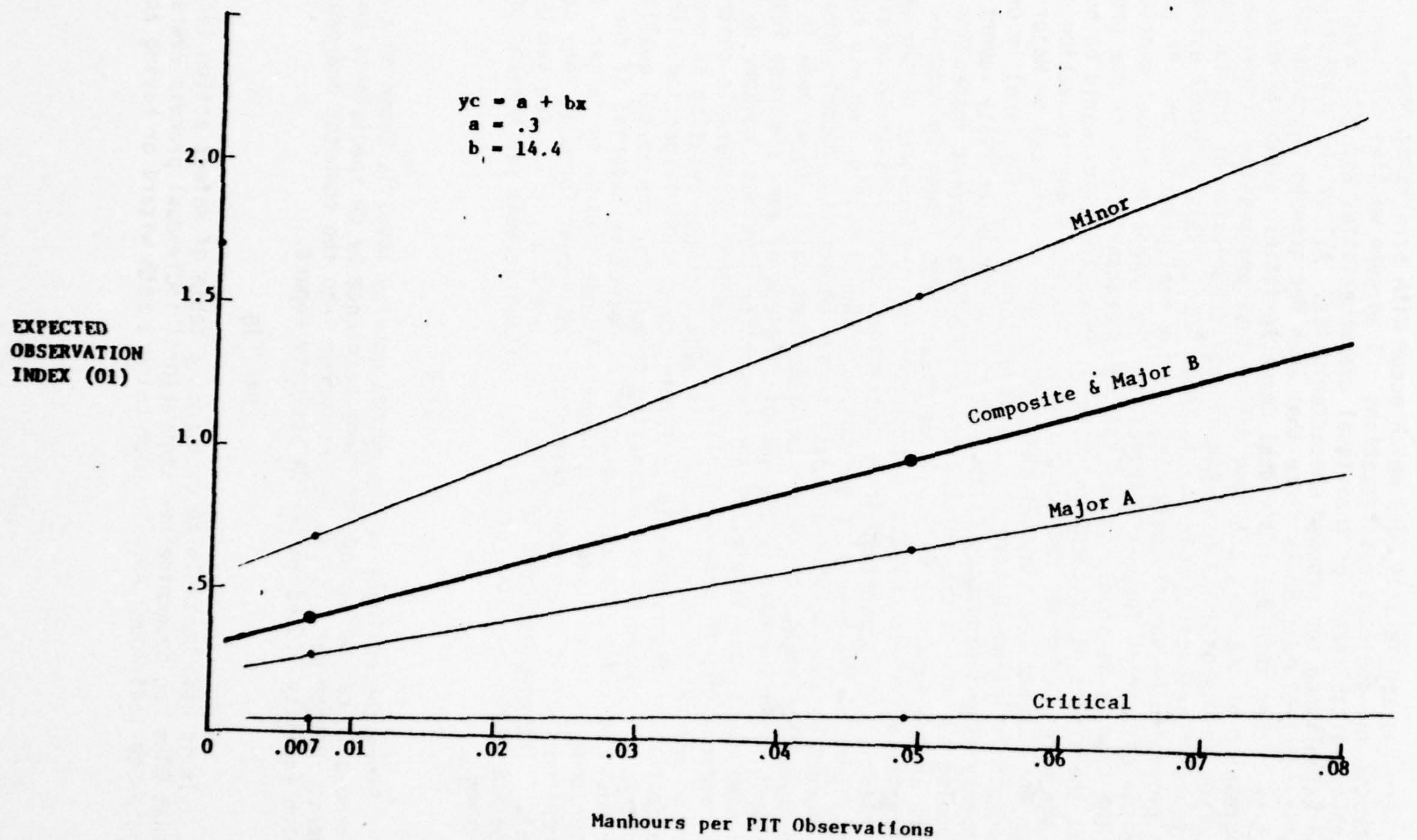


CHART 16

NORMAL QUALITY LEVEL (Composite and/or Major Characteristics)

PIT Hrs./Count	0	1	2	3	4	5	6	7	8	9
.00	.3000	.3144	.3288	.3432	.3576	.3720	.3864	.4008	.4152	.4296
.01	.4440	.4584	.4728	.4872	.5016	.5160	.5304	.5448	.5592	.5763
.02	.5880	.6024	.6168	.6312	.6456	.6600	.6744	.6888	.7032	.7176
.03	.7320	.7464	.7608	.7752	.7896	.8040	.8184	.8328	.8472	.8616
.04	.8760	.8904	.9048	.9192	.9336	.9480	.9624	.9768	.9912	1.0056
.05	1.0200	1.0344	1.0488	1.0632	1.0776	1.0920	1.1064	1.1208	1.1352	1.1496
.06	1.1640	1.1784	1.1928	1.2072	1.2216	1.2360	1.2504	1.2648	1.2792	1.2936
.07	1.3080	1.3224	1.3368	1.3512	1.3656	1.3800	1.3944	1.4088	1.4232	1.4376
.08	1.4520	1.4664	1.4808	1.4952	1.5096	1.5240	1.5384	1.5528	1.5672	1.5816
.09	1.5960	1.6104	1.6248	1.6392	1.6536	1.6680	1.6824	1.6968	1.7112	1.7256
.10	1.7400	1.7544	1.7688	1.7832	1.7976	1.8120	1.8264	1.8408	1.8552	1.8696
.11	1.8840	1.8984	1.9128	1.9272	1.9416	1.9560	1.9704	1.9848	1.9992	2.0136
.12	2.0280	2.0424	2.0568	2.0712	2.0856	2.100	2.1144	2.1288	2.1432	2.1576
.13	2.1720	2.1864	2.2008	2.2152	2.2296	2.2440	2.2584	2.2728	2.2872	2.3016
.14	2.3160	2.3304	2.3448	2.3592	2.3736	2.3880	2.4024	2.4168	2.4312	2.4456
.15	2.4600	2.4744	2.4888	2.5032	2.5176	2.5320	2.5464	2.5608	2.5752	2.5896
.16	2.6040	2.6184	2.6328	2.6472	2.6616	2.6750	2.6904	2.7048	2.7192	2.7336
.17	2.7480	2.7624	2.7768	2.7912	2.8056	2.8200	2.8344	2.8488	2.8632	2.8776
.18	2.8920	2.9064	2.9208	2.9352	2.9496	2.9640	2.9784	2.9928	3.0072	3.0216
.19	3.0360	3.0504	3.0648	3.0792	3.0936	3.1080	3.1224	3.1368	3.1512	3.1656
.20	3.1800	3.1944	3.2088	3.2232	3.2376	3.2520	3.2664	3.2808	3.2952	3.3096
.21	3.3240	3.3384	3.3528	3.3672	3.3816	3.3960	3.4104	3.4248	3.4392	3.4536
.22	3.4680	3.4824	3.4968	3.5112	3.5256	3.5400	3.5544	3.5688	3.5832	3.5976
.23	3.6120	3.6264	3.6408	3.6552	3.6696	3.6840	3.6984	3.7128	3.7272	3.7416
.24	3.7560	3.7704	3.7848	3.7992	3.8136	3.8280	3.8424	3.8568	3.8712	3.8856
.25	3.9000	3.9144	3.9288	3.9432	3.9576	3.9720	3.9864	4.0008	4.0152	4.0296

CHART 17

GUIDE:

DEFECT ACTION LIMITS

FOR PROCESS AVERAGES WHICH ARE COMPARABLE TO STANDARD AQLs

NUMBER OF SAMPLE UNITS OR OBSERVATIONS	ACCEPTABLE QUALITY LEVEL																									
	.010	.015	.025	.040	.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000
20 - 29	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	3	4	6	10	16	25	38	63	100	163	250
30 - 49	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	2	4	6	10	15	25	38	57	95	152	247	380
50 - 79	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	3	4	7	10	16	26	42	65	98	163	260	422	
80 - 129	⁑	⁑	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	3	4	7	11	16	26	42	68	105	158	263	420		
130 - 199	⁑	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	2	4	7	11	17	25	41	66	107	165	248	410			
200 - 319	⁑	⁑	⁑	⁑	⁑	⁑	0	0	1	2	3	4	7	10	17	26	39	65	104	169	260	390				
320 - 499	⁑	⁑	⁑	⁑	⁑	0	0	1	2	3	4	6	10	16	26	41	61	101	162	263	405					
500 - 799	⁑	⁑	⁑	⁑	0	0	1	2	3	4	7	11	16	26	42	65	98	162	260	422						
800 - 1249	⁑	⁑	⁑	0	0	1	2	3	4	7	10	16	26	41	67	102	154	256	410							
1250 - 1999	⁑	⁑	0	0	1	2	2	4	6	10	16	24	40	64	104	160	240	400								
2000 - 3149	⁑	0	0	1	2	3	4	6	10	17	26	39	64	103	167	257	336									
3150 - 4999	0	0	1	2	3	4	6	10	16	26	41	61	102	163	265	407										
5000 - 7999	0	1	2	3	4	7	10	16	26	42	65	98	163	260	422											
8000 - 12499	1	2	3	4	7	10	15	26	41	67	102	154	256	410												
12500 - 19999	2	2	4	6	10	16	24	40	64	104	160	241	400													
20000 - 31499	3	4	6	10	16	25	38	63	100	162	251	375														
31500 - 49999	4	6	10	15	25	38	57	95	152	247	380															
50000 & OVER	5	8	13	20	33	50	75	125	200	325																

⁑ DENOTES THAT THE NUMBER OF SAMPLE UNITS FROM THE LAST LOTS OR BATCHES IS NOT SUFFICIENT FOR REDUCED INSPECTION FOR THIS AQL. IN THIS INSTANCE MORE LOTS OR BATCHES MAY BE USED FOR THE CALCULATION, PROVIDED THAT THE LOTS OR BATCHES USED ARE THE MOST RECENT ONES IN SEQUENCE, THAT THEY HAVE ALL BEEN ON NORMAL INSPECTION, AND THAT NONE HAS BEEN REJECTED WHILE ON ORIGINAL INSPECTION.

CHART 18

a computer. For example, if a contractor is working to an AQL of 1.0 and has inspected 1000 units, the process average would exceed the AQL if more than 10 defects were observed and the QAR should do some additional inspection to assure that the contract quality requirements are complied with.

Now simply by comparing the estimated normal quality level to the QARs observed defectiveness (the observation index) it is possible to construct a new weighting factor (based on the should-see, did-see concept) that represents that portion of the QARs product inspection effort that is supportable from a product quality (or the lack of it) point of view.

CHART 19

Applying this new statistic to that old 1971 composite observation, you can see that most, but not all, of the QARs product inspection effort is supportable from a product quality point of view. The QA branches, strong in mechanical effort, still need to be looked at, but look at what has happened to the munitions branches D5, A12 and A43. They have moved in line with the mechanical branches suggesting that some of the effort (possibly even the mandatory characteristics) could be reduced because of product quality. A very interesting development.

CHART 20

So far I have only talked about all of these nice calculations and have shown you how they effect a scatter diagram. Here is how the calculations are actually made and how standards can be applied to measure effectiveness. (Note: The observation earning rate, the normal quality level, and the defect earning rate.)

CHART 21

This is how the national picture looked in October 1970 when viewed through normal quality analysis. As you can see, Atlanta and San Francisco reported much more product defectiveness in their data than average, while New York and Philadelphia reported much less.

CHART 22

In July 1971 the picture was much the same except it looked like Chicago was moving toward Atlanta and San Francisco and Detroit joined New York and Philadelphia.

CHART 23

A look at the normal quality analysis for the National data. The contributing factor for the computed effectiveness levels was the defect earning rate.

PLOTTING SYMBOLS

★ REGION
⊡ DISTRICT
⊙ OFFICE
△ DIVISION
✱ BRANCH
● QAR

QUALITY ASSURANCE

NORMAL QUALITY WORK EFFORT

(PIT OBSERVATIONS ADJUSTED FOR COMPOSITE COUNT AND NORMAL QUALITY LEVEL)

Q 30b 3

DECEMBER 1970

DCASR CHICAGO

$y_c = a + bx$
$a = .2364$
$b = .01456$
$S_{yx} = .2801$

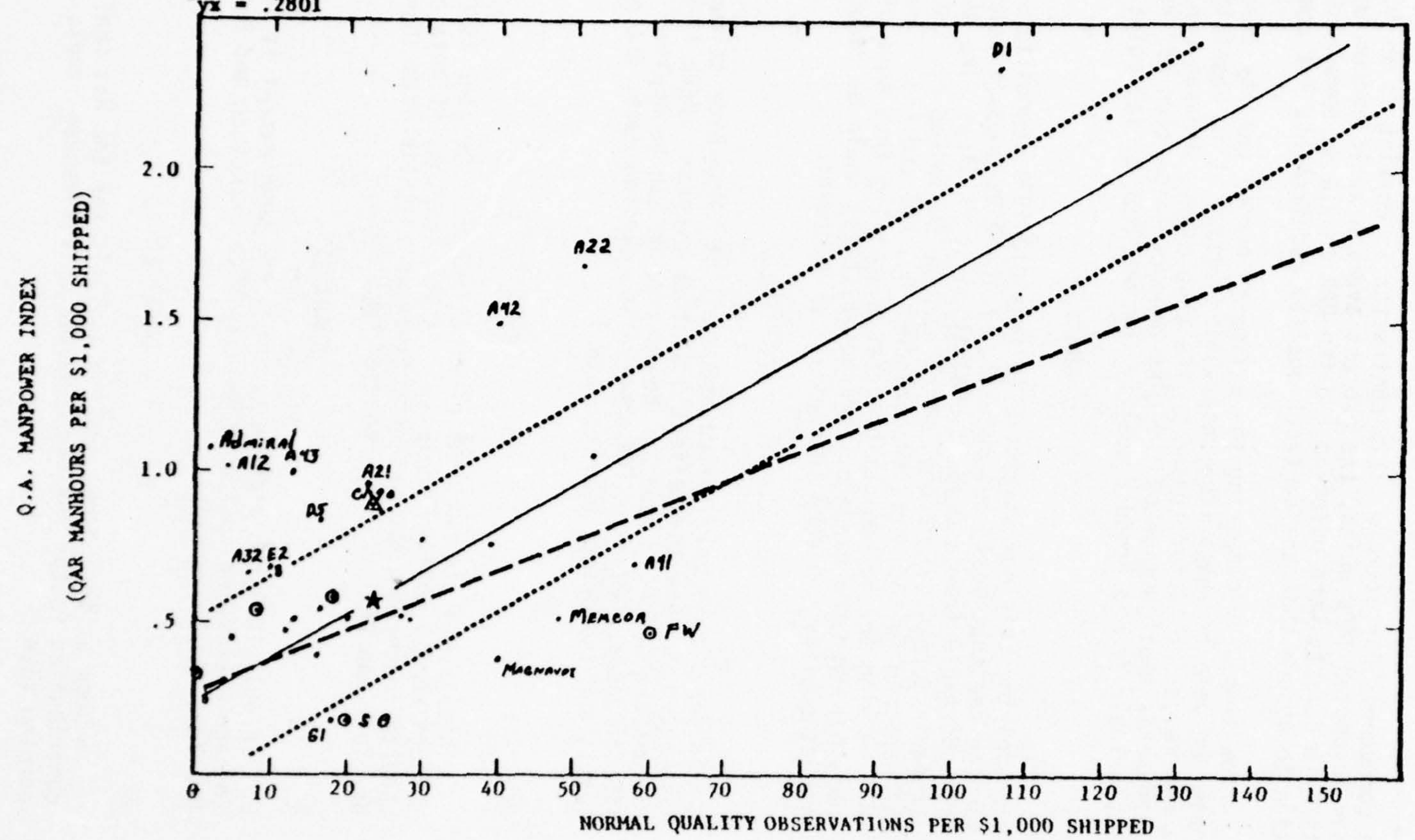


CHART 19

Q 19a-0

DCASR CHICAGO

NORMAL QUALITY ANALYSIS

October 1970

CALCULATION	FACTOR	CHICAGO OPS	ROCKFORD	MILW. HQ.	DELCO	IND. HQ.	FORT WAYNE	SOUTH BEND	REGION
A. (376 data)	PIT Obs. (Oct.)	1275557	42,701	774016	37	651830	221143	227621	3,192,900
B. (376 data)	MH/PIT Obs.	.011	.030	.010	.243	.007	.018	.009	.011
C. B ÷ .007	Obs. Earning Rate	1.571	4.286	1.429	34.712	1.000	2.571	1.286	1.571
D. 14.4B + .3	Normal Quality Level	.458	.732	.444	3.799	.401	.559	.430	.458
E. (376 data)	Observation Index	.18	.18	.16	2.70	.22	.78	.67	.26
F. E ÷ D	Defect Earning Rate	.393	.246	.360	.711	.549	1.395	1.558	.568
G. (376 data)	Value Shipped (000)	33,240	5,542	25,508	1,933	19,253	13,445	23,005	121,926
H. A ÷ G	Obs/$1000 Ship	38.374	7.705	30.344	.019	33.856	16.448	4.894	26.187
I. H·C·F	Earned Obs/$1000 Shp.	23.692	8.124	15.610	.471	18.587	58.991	19.824	23.367
J. .01I + .25	Earned MH/$1000	.487	.331	.406	.255	.436	.840	.448	.484
K. (376 data)	Actual MI (MH/$1000)	.89	.54	.58	.34	.59	.47	.17	.57
L. J ÷ K x 100	% Effectiveness	54.71	61.33	70.00	75.00	73.89	178.72	263.64	84.91

CHART 20

NATIONAL NORMAL QUALITY WORK EFFORT

OCTOBER 1970

Q 29a

DCASR CHICAGO

Yc = a + bx

Std Line (1968)

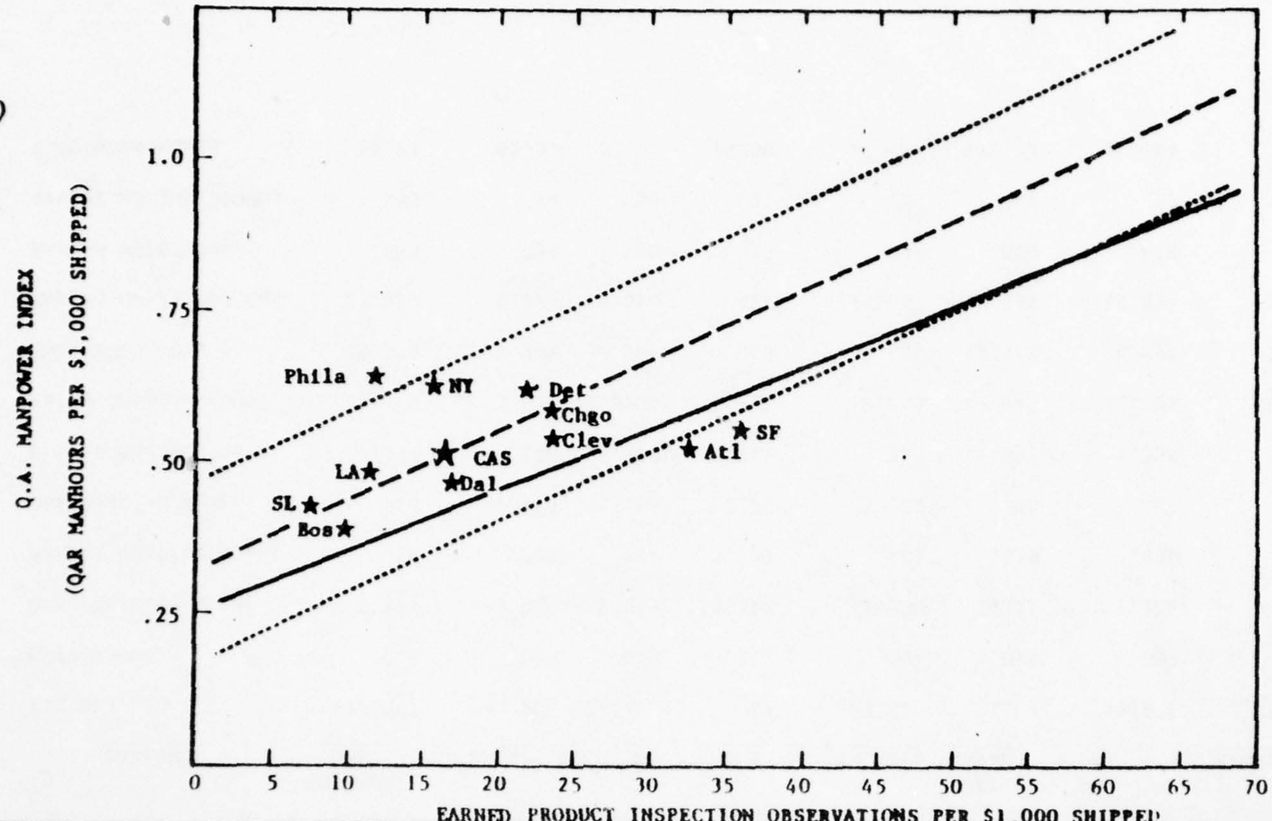
a = .2500

d = .0100

Actual Line (Oct 70)

a = .3109

d = .0116



ACTIVITY	CAS	ATL	BOS	CHGO	CLEV	DAL	DET	L.A.	N.Y.	PHL.	S.L.	S.F.
Value Shipped (Millions)	1442.6	120.2	281.9	121.9	80.3	110.5	49.4	220.4	138.3	130.8	115.1	73.7
Actual PIT obs./$1000	20.4	39.4	13.7	26.2	20.8	16.3	8.3	12.1	22.0	36.3	23.2	9.5
Earned PIT obs./$1000	16.6	32.7	10.2	23.6	23.7	17.2	22.2	11.5	15.9	11.0	8.0	36.7
Earned QAR MH/$1000	.416	.577	.352	.486	.487	.422	.472	.365	.409	.370	.330	.616
Actual QAR MH/$1000	.51	.52	.39	.58	.54	.47	.62	.48	.62	.64	.42	.56
Effectiveness	81.9	110.4	89.2	84.3	89.5	88.8	76.7	76.7	66.6	57.7	79.2	111.0

CHART 21

QUALITY ASSURANCE

NORMAL QUALITY WORK EFFORT

JULY 1971

DCASR CHICAGO

PLOTTING SYMBOLS

- ★ REGION
- ⊡ DISTRICT
- ⊙ OFFICE
- △ DIVISION
- ✱ BRANCH
- ● QAR

Yc = a + bx

STD LINE (1968)
a = .250
b = .010

ACTUAL LINE
a = .245
b = .013

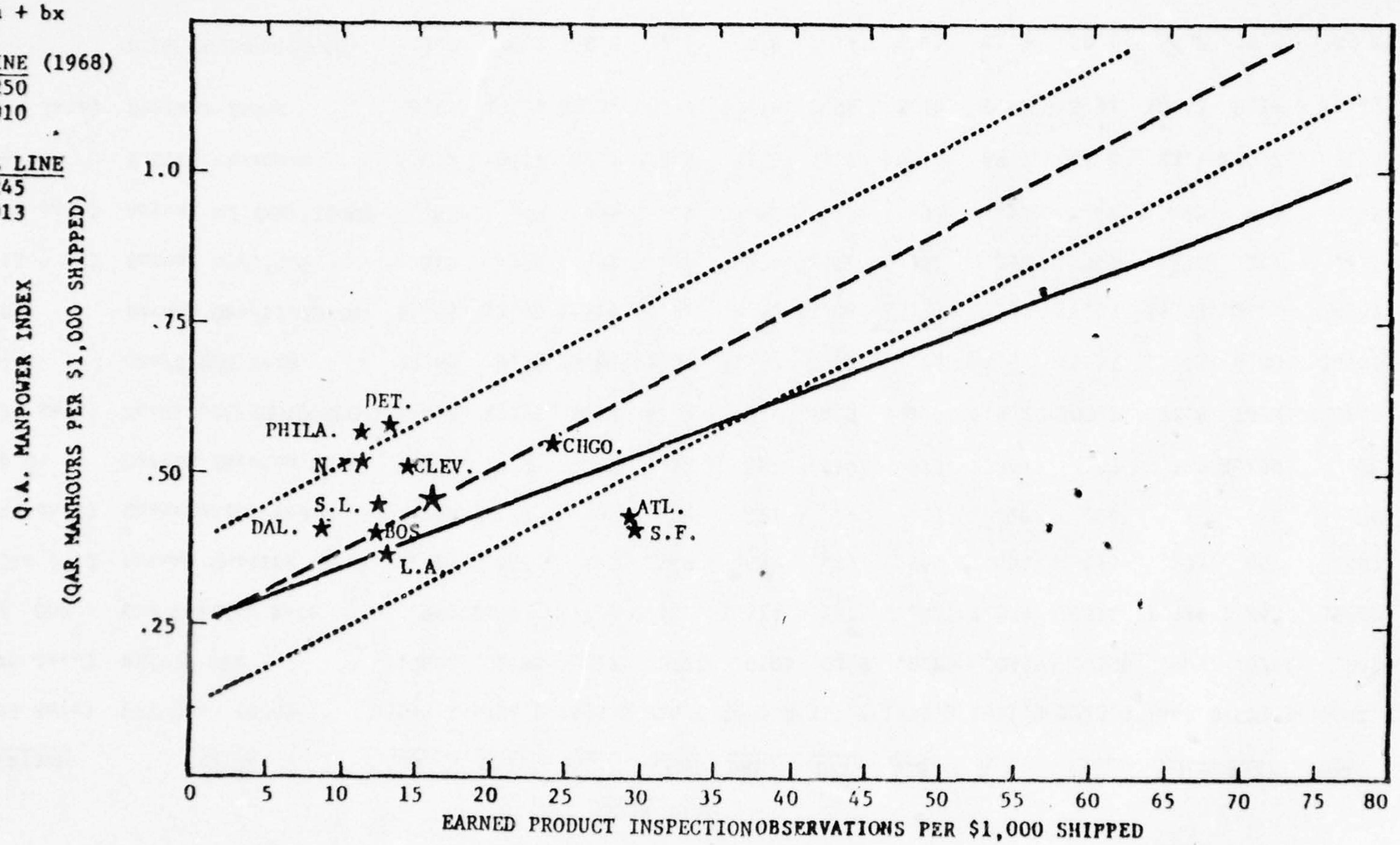


CHART 22

Q 19a

NATIONAL NORMAL QUALITY ANALYSIS

JULY 1971

CALCULATION	FACTOR	ATL.	BOS.	CHI.	CLE.	DAL.	DET.	L.A.	N.Y.	PHI.	S.L.	S.F.	CAS
A. (376 data)	PIT Obs (000)	3143.3	1794.1	1655.0	726.6	1065.8	397.7	1855.3	1891.3	2223.3	1669.9	522.3	16944.7
B. (376 data)	MH/PIT Obs	.0066	.0185	.0125	.0172	.0106	.0249	.0185	.0135	.0106	.0092	.0255	.0130
C. B ÷ .007	Obs Earning Rate	.943	2.643	1.786	2.457	1.514	3.557	2.643	1.929	1.514	1.314	3.643	1.857
D. 14.4B + .3	Normal Quality Level	.395	.566	.480	.548	.453	.659	.566	.494	.453	.433	.667	.487
E. (376 data)	Observation Index	.43	.29	.34	.28	.21	.27	.37	.18	.16	.19	.80	.30
F. E ÷ D	Defect Earning Rate	1.089	.512	.708	.511	.464	.410	.653	.364	.353	.439	1.199	.616
G. (376 data)	VALUE SHIPPED(000000)	110.3	192.1	86.7	62.9	89.0	44.3	344.6	118.2	103.2	77.8	76.8	1206.0
H. A ÷ G	Obs/$1000 Ship.	28.49	9.34	19.08	11.55	11.97	8.97	7.59	16.01	21.54	21.45	6.80	14.05
I. H·C·F	Earned Obs/$1000 Sh.	29.25	12.64	24.14	14.51	8.41	13.08	13.10	11.24	11.53	12.39	29.71	16.07
J. .01I + .25	Earned MH/$1000	.543	.376	.491	.395	.334	.381	.381	.362	.365	.374	.547	.411
K. (376 data)	Actual MI (MH/$1000)	.43	.40	.53	.51	.41	.58	.37	.52	.57	.45	.42	.45
L. J ÷ K	% Effectiveness	126.2	94.1	92.7	77.5	81.5	65.7	103.0	69.7	64.1	83.1	130.3	91.3
M. (376 data)	Systems Index	8.15	10.51	10.32	10.97	10.16	6.94	7.86	9.92	6.92	10.48	8.36	9.12
	TOTAL MANHOURS(000)	49.7	76.2	46.3	32.3	36.8	25.7	90.1	61.9	59.1	35.0	32.3	545.1

CHART 23

CHART 24

So we dug down in the tool box once again and hauled out the old but trustworthy frequency distribution chart and applied it to the National data for August 1971. This time we were looking for reasons why there was so much variation in the defect earning rate (the ration between the normal quality level and the observation rate). Here we plotted each region's data individually. As you can see, every region was different. However, there was a very strong tendency for the lobes to form suggesting a strong possibility that some assignable causes may be identifiable.

CHART 25

This chart shows the same data for all regions combined. It was soon apparent that because QARs could not report product defectiveness observed during the concurrent (test surveillance) type of inspection that the observation index was a biased statistic.

CHART 26

In June of 1972 we finally convinced the CAS-Q staff to let QAR's report defectiveness observed during concurrent inspection in their observation index. At the same time CAS gave up on the observation work count and changed the term to samples inspected. Unfortunately when the National observation index climbed to well over 1% defective, it disturbed some very influentual people and in December of 1972 it was changed to end items inspected and no reporting of observed defectiveness while performing concurrent inspection. Here you can see the effect the numbers game had on the normal quality analysis while there was very little effect on real effectiveness. (Note: The changes in the observation rate, the defect earning rate, and the value of the estimated line.)

CHART 27

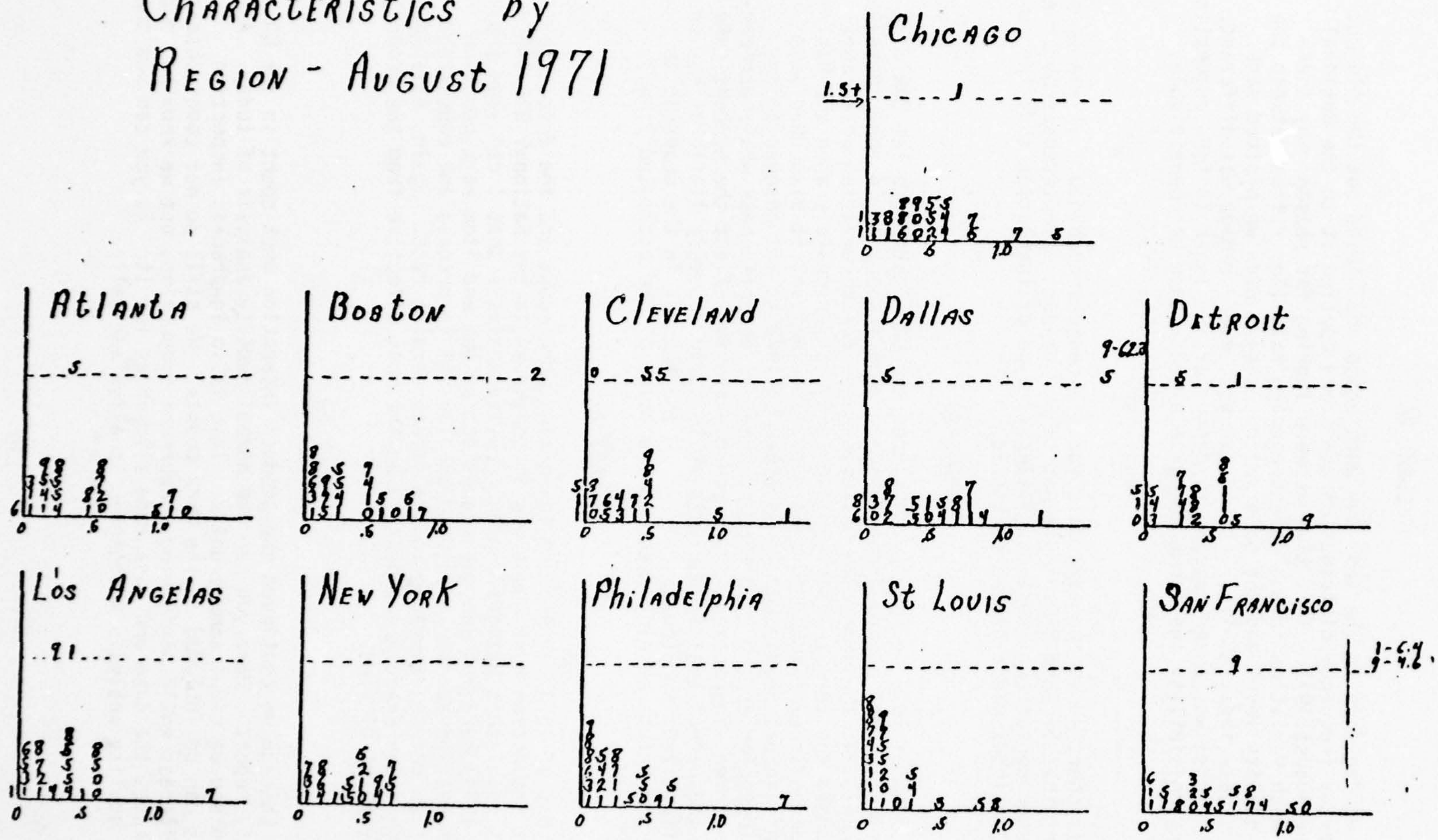
In May of 1974 the product inspection work count and the defective product inspection work count was discontinued in the National RCS 448. This is the latest National normal quality analysis that I can show you. (April 1974) here you can see the effect of the end item work count on the observation earning rate, and the loss of in-process and concurrent inspection defect reporting in the defect earning rate. Again, Atlanta, Dallas and San Francisco appear to be the most effective from the product quality point of view.

CHART 28

In Chicago we continued the product inspection work count in the QA activity report. Here you see the normal quality analysis of today. As you can see we count sample units. This is so in-process inspection results can be included in the work counts. We still do not count observed defectiveness while performing concurrent inspection, but we know how much this biases the data and have made allowances for it. As you can see the normal quality analysis technique is alive and well.

10-3-71

Quality Reporting Characteristics by Region - August 1971



DEFECT EARNING RATE $\left(\frac{\text{OBSERVATION INDEX}}{\text{NORMAL QUALITY LEVEL}}\right)$

CHART 24

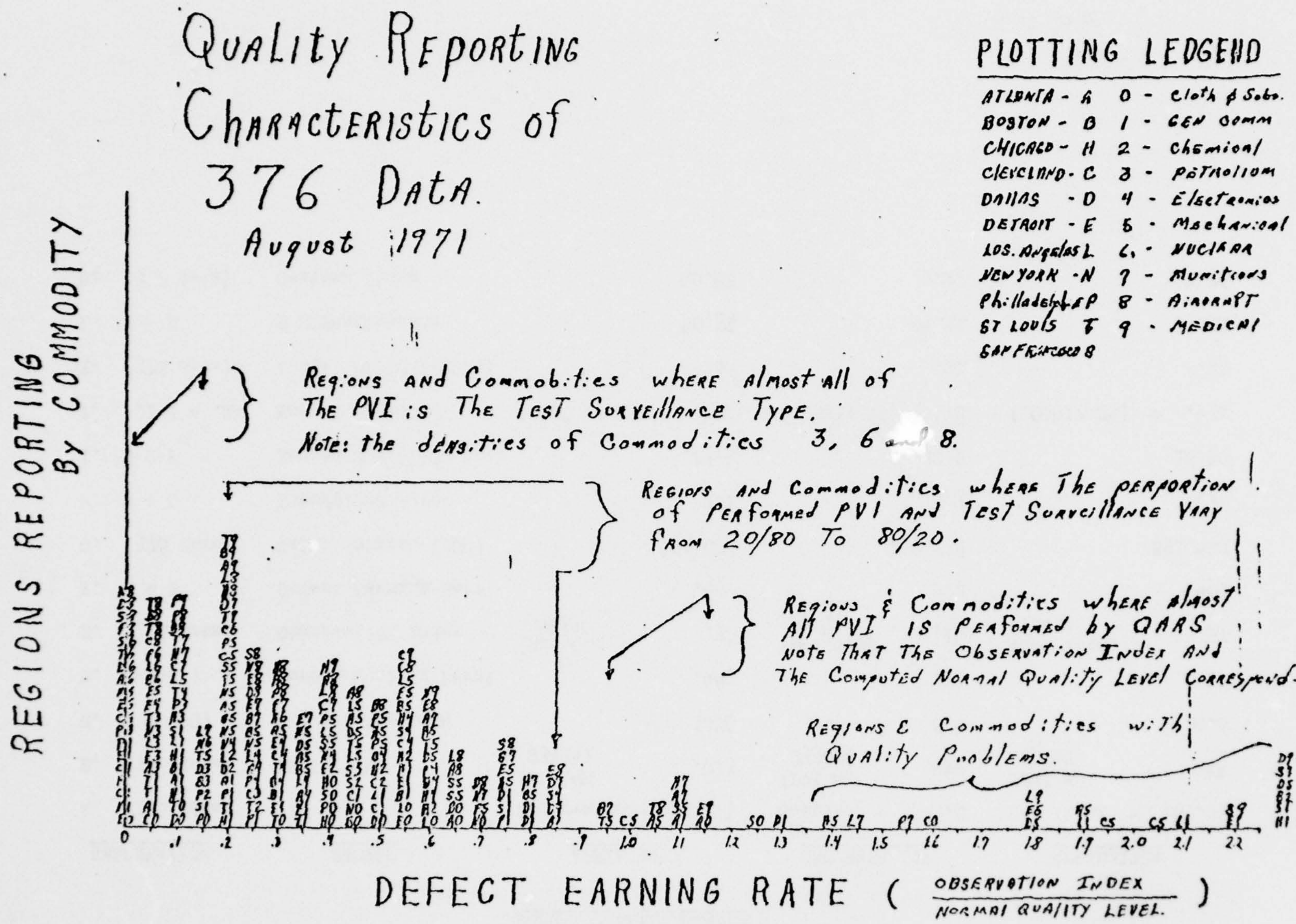

Quality Reporting Characteristics of 376 Data.
August 1971
PLOTTING LEDGEND
ATLANTA - A
BOSTON - B
CHICAGO - H
CLEVELAND - C
DALLAS - D
DETROIT - E
LOS ANGELES L
NEW YORK - N
PHILLADELPHIA P
ST LOUIS T
SAN FRANCISCO S
0 - Cloth & Sobs.
1 - GEN COMM
2 - Chemical
3 - Petroliom
4 - Electronics
5 - Mechanical
6 - Nuclear
7 - Munitions
8 - Aircraft
9 - Medical
Regions and Commobities where almost all of The PVI is The Test Surveillance Type.
Note: the densities of Commodities 3, 6 and 8.
Regions and Commodities where The perportion of Performed PVI and Test Surveillance Vary from 20/80 To 80/20.
Regions & Commodities where almost All PVI is Performed by QARS
Note That The Observation Index and The Computed Normal Quality Level Correspond.
Regions & Commodities with Quality Problems.
REGIONS REPORTING BY COMMODITY
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
DEFECT EARNING RATE (OBSERVATION INDEX / NORMAL QUALITY LEVEL.)

CHART 25

DCASR CHICAGO

NORMAL QUALITY ANALYSIS

CALCULATION	FACTOR	APRIL 1972		DECEMBER 1972		APRIL 1974	
A. (376 data)	PIT Item	Observations	1770.1	Samples =	392.8	End Items =	179.95
B. (376 data)	MH/PIT Obs	(PVI MH 23474)	.013	(PVI MH 23308)	.059	(PVI MH 26057)	.144
C. B ÷ .007	Obs Earning Rate		1.86		8.4		20.6
D. 14.4B + .3	Normal Quality Level		.487		1.15		2.37
E. (376 data)	Observation Index	(Def Obs 5781)	.32	(Def Samp 4502)	1.14	(Def Items 1747)	.97
F. E ÷ D	Defect Earning Rate		.657		.992		.409
G. (376 data)	Value Shipped (000)		$92,678		$99,739		$91,882
H. A ÷ G	Item/$1000 Ship.		19.1		3.9		1.96
I. H·C·F	Earned Obs/$1000 Sh.		23.3		32.9		16.46
J. .014I + .24	Earned MH/$1000	(.01I + .25) =	.483	(.007I+.25) =	.48	(.014I+.24) =	.471
K. (376 data)	Actual MI (MH/$1000)		.56		.51		.55
L. J ÷ K	% Effectiveness		86.3%		94.2%		85.5%
M. (376 data)	Systems Index		10.88		9.29		7.76

CHART 26

NATIONAL NORMAL QUALITY ANALYSIS

APRIL 1974

	CALCULATION	FACTOR	ATL.	BOS.	CHI.	CLE.	DAL.	DET.	L.A.	N.Y.	PHI.	S.L.	S.F.	CAS
A.	(376 data)	PIT Item (000)	237.0	291.8	179.9	124.7	140.3	92.77	388.8	457.0	356.2	319.2	95.46	2683.6
B.	(376 data)	MH/PIT Obs	.137	.145	.144	.154	.145	.118	.111	.078	.098	.069	.216	.115
C.	B ÷ .007	Obs Earning Rate	19.57	20.7	20.6	22.0	20.7	16.9	15.86	11.14	14.0	9.86	30.91	16.4
D.	14.4B + .3	Normal Quality Level	2.27	2.40	2.37	2.51	2.38	1.99	1.90	1.42	1.71	1.30	3.42	1.95
E.	(376 data)	Observation Index	2.01	1.00	.97	1.24	1.01	1.17	.88	.70	.80	.51	1.87	.98
F.	E ÷ D	Defect Earning Rate	.883	.416	.409	.493	.423	.587	.466	.493	.465	.391	.543	.503
G.	(376 data)	Value Shipped($Mil)	136.7	203.6	91.9	69.9	149.9	39.0	210.9	111.6	133.3	104.4	137.0	1387.1
H.	A ÷ G	Item/$1000 Ship.	1.73	1.43	1.96	1.78	.936	2.38	1.84	4.10	2.67	3.06	.697	1.93
I.	H·C·F	Earned Obs/$1000 Sh.	29.96	12.37	16.46	19.37	8.21	23.53	13.61	22.48	17.41	11.78	11.70	15.99
J.	.014I + .24	Earned MH/$1000	.659	.413	.471	.511	.355	.569	.431	.555	.484	.405	.404	.464
K.	(376 data)	Actual MI (MH/$1000)	.469	.455	.555	.579	.333	.573	.457	.630	.519	.438	.296	.463
L.	J ÷ K	% Effectiveness	140.6	90.8	85.5	88.3	106.6	99.4	94.2	88.1	93.2	92.6	136.4	100.2
M.	(376 data)	Systems Index	6.67	8.32	7.76	8.67	7.36	7.55	7.23	5.88	4.07	7.85	7.39	7.06

CHART 27

MAY 1977

DCASR CHICAGO

NORMAL QUALITY ANALYSIS

CALCULATION	FACTOR		REGION TOTAL
A. (Data)	PVI Hours		20,158
B. (Data)	PIT Samples	Sample Units	214,919
C. A ÷ B	MH/PIT		.094
D. C ÷ .007	Obs Earning Rate		13.4
E. 14.4C + .3	Normal Quality Level		1.65
F. (Data)	Defects Observed	Defective Units	2,319
G. F ÷ B x 100	Observation Index		1.079
H. F ÷ E	Defect Earning Rate		.654
I. (Data)	Value Shipped (000)		$120,288.2
J. B ÷ I	Sample/$1000 Ship		1.787
K. J · H · C	Earned Obs/$1000 Ship:		15.65
L. (Data)	Total Manhours		46,721
M. L ÷ I	Actual MH/$1000		.388
N. .112K + .25	Earned MH/$1000		.425
O. N ÷ M · 100	% Effectiveness		109.5
P. (Data)	Systems Index		7.30

CHART 28

CHART 29

Here you can see the analysis as it applies to the DCASMAS and DCASPROS. DCASMA, Indianapolis is approaching the tolerance level and will be looked at during a management review in August. DCASPRO, Sundstrand is deeply involved with NASA and the space shuttle and because of concurrent inspection on critical characteristics has not reported a single observed defect in over two months.

CHART 30

In previous region normal quality analysis you may have noticed that DCASMA South Bend always has a high percentage of effectiveness. Here you can see why. Blaw-Knox produces armor steel castings for the M-60 tank, tank hulls, turrents, and gun shields. We have quality problems but very little authority to initiate corrective action. Defective castings end up being shipped to the prime contractor who repairs the casting and bills Blaw-Knox. Sometimes we wonder why we are in the plant - we seem to be doing the prime contractor's job for him. In A. M. General Corporation we sample vehicles and drive them around the test track. There is very little concurrent inspection. As you can see the defect earning rate is almost 1.969. This is hardly the PQAP described by ASPR, but TACOM is satisfied with our work. Even when you exclude those two plants from the analysis, it is quite obvious that most of the QARs in South Bend are working very proficiently.

CHART 31

Even when you look at the region without Blaw-Knox and A. M. General you can see that we can support our expenditure of QA manpower from a product quality point of view and you must conclude that we are actively engaged in implementing the requirement of ASPR 14-403.

CHART 32

Why does normal quality analysis work at the facility level? Because PQAP works at the facility level. A summary of PQAP, as defined by ASPR, shows that QARs have the authority to use contractor data to accept material and/or to identify those characteristics where he should be performing additional product inspection.

CHART 33

What is the potential for reducing Government PQA to a minimum consistent with proper assurance that the supplies or services accepted conform to contract quality requirements? The answer to that question is best demonstrated by this chart. You can readily see that by using the principle of characteristics selection and the product verification R levels, it would be possible to reduce the ratio of contractor inspection personnel to Government inspection personnel to the 100 to 1 level and below. As long as QARs are performing product verification inspection on characteristics where the contractors process average is less than AQL and the contractor generates reliable quality data, there is the potential of reducing Government PQA effort.

MAY 1977

DCASR CHICAGO

NORMAL QUALITY ANALYSIS

CALCULATION	FACTOR	CHICAGO	MILWAUKEE	INDIANAPOLIS	FT. WAYNE	SUNDSTRAND
			DCASMA			DCASPRO
A. (Data)	PVI Hours	7742	4633	2323	2280	806
B. (Data)	PIT Samples	107393	66114	17427	14134	495
C. A ÷ B	MH/PIT Obs	.072	.070	.133	.161	1.628
D. C ÷ .007	Obs Earning Rate	10.30	10.0	19.0	23.0	232.6
E. 14.4C + .3	Normal Quality Level	1.34	1.31	2.22	2.62	23.7
F. (Data)	Defects Observed	965	364	229	278	0
G. F ÷ B x 100	Observation Index	.90	.551	1.31	1.97	0.0
H. F ÷ E	Defect Earning Rate	.672	.421	.592	.750	0.0
I. (Data)	Value Shipped (000)	$27,862.5	$20,751.5	$10,234.5	$11,013.7	$2,619.4
J. B ÷ I	Sample/$1000 Ship.	3.85	3.18	1,703	1.283	.189
K. J · H · C	Earned Obs/$1000 Ship.	26.7	13.4	19.2	22.2	.000
L. (Data)	Total Manhours	15,539	9,389	5,991	5,709	1,680
M. L ÷ I	Actual MH/$1000	.558	.452	.585	.518	.641
N. .112K + .25	Earned MH/$1000	.549	.400	.465	.498	.250
O. N ÷ M · 100	% Effectiveness	98.4	88.5	79.4	96.1	39.0
P. (Data)	Systems Index	5.96	3.95	4.95	12.39	8.34

CHART 29

DCASR CHICAGO

MAY 1977

NORMAL QUALITY ANALYSIS

CALCULATION	FACTOR	DCASMA SO. BEND	BLAW-KNOX	AMG	SO. BEND LESS BLAW KNOX & AMG
A. (Data)	PVI Hours	2,126	518	719	889
B. (Data)	PIT Samples	8,626	784	1,276	6,566
C. A ÷ B	MH/PIT Obs	.246	.661	.563	.135
D. C ÷ .007	Obs Earning Rate	35.2	94.4	80.5	19.3
E. 14.4C + .3	Normal Quality Level	3.85	9.81	8.41	2.25
F. (Data)	Defects Observed	472	243	104	125
G. F ÷ B x 100	Observation Index	5.47	30.99	8.15	1.90
H. F ÷ E	Defect Earning Rate	1.42	3.158	.969	.846
I. (Data)	Value Shipped (000)	$26,830.4	$5201.0	$6989.3	$14,640.1
J. B ÷ I	Sample/$1000 Ship.	.322	.151	.183	.448
K. J · H · C	Earned Obs/$1000 Ship.	16.1	44.9	14.2	7.34
L. (Data)	Total Manhours	6,286	991	1,179	4,116
M. L ÷ I	Actual MH/$1000	.234	.191	.169	.281
N. .112K + .25	Earned MH/$1000	.430	.753	.409	.332
O. N ÷ M · 100	% Effectiveness	183.6	395.3	242.7	118.2
P. (Data)	Systems Index	8.74	11.17	7.99	8.01

CHART 30

MAY 1977

DCASR CHICAGO

NORMAL QUALITY ANALYSIS

CALCULATION	FACTOR	REGION TOTAL LESS BLAW-KNOX & AMG
A. (Data)	PVI Hours	18,921
B. (Data)	PIT Samples	212,859
C. A ÷ b	MH/PIT Obs	.089
D. C ÷ .007	Obs Earning Rate	12.7
E. 14.4C + .3	Normal Quality Level	1.58
F. (Data)	Defects Observed	1,972
G. F ÷ E x 100	Observation Index	.93
H. F ÷ E	Defect Earning Rate	.586
I. (Data)	Value Shipped (000)	$108,097.9
J. B ÷ I	Sample/$1000	1.97
K. J · H · C	Earned Obs/$1000 Ship.	14.7
L. (Data	Total Manhours	44,551
M. L ÷ I	Actual MH/$1000	.412
N. .112K + .25	Earned MH/$.000	.414
O. N - M · 100	% Effectiveness	100.5
P. (Data)	Systems Index	7.17

CHART 31

SUMMARY OF PQAP

1. CONTRACT REQUIREMENT FOR OR CONTRACTOR AGREEMENT TO: ESTABLISH AND MAINTAIN A QUALITY OR INSPECTION SYSTEM.

2. QAR WILL (MONITOR THE SYSTEM)
   - A. INITIALLY REVIEW THE CONTRACTOR'S PROCEDURES.
   - B. PERIODICALLY EVALUATE THE CONTRACTORS COMPLIANCE TO THE PROCEDURES
   - C. RANDOMLY AUDIT THE CONTRACTORS SYSTEM
   - D. ALWAYS INITIATE CORRECTIVE ACTION FOR OBSERVED DEFECTIVENESS OR FAILURE.

3. QAR WILL EVALUATE OBJECTIVE QUALITY DATA.
   - A. ACCEPT MATERIAL WHEN DATA PROVIDES ADEQUATE ASSURANCE THAT CONTRACT REQUIREMENTS ARE MET.
   - B. DETERMINE WHICH QUALITY CHARACTERISTICS MAY NOT MEET CONTRACT REQUIREMENTS.
   - C. TAKES CORRECTIVE ACTION FOR OBSERVED FAILURE.

4. QAR WILL PERFORM PRODUCT VERIFICATION INSPECTION
   - A. AS REQUESTED BY PCO.
   - B. FOR QUALITY CHARACTERISTICS WHICH HAVE HIGH PROBABILITY OF DEFECTIVENESS.
   - C. CHARACTERISTICS WHICH HAVE BEEN DEFECTIVE. (PREVIOUS REJECTION OR CUSTOMER COMPLAINT)
   - D. TAKES CORRECTIVE ACTION FOR OBSERVED DEFECTIVENESS IN EXCESS OF CONTRACT REQUIREMENTS.

GENERATING & USING QUALITY DATA

	CONTRACTOR INSPECTION	GOV'T. INSPECTION		
5 Lots	60,000	60,000	60,000	60,000
Samples	N-500	R5 (100)	R1 (500)	R5 (100)
AQL Maj.	1.5 Group	1.5Group		
	.4 Char.	.4 Char.	.4 Char.	.4 Char.
DEFECTS		FOUND		
101	1		NA	NA
102				
103				
104	4	1		
105				
106				
107	1			
108				
109			NA	NA
110	15	3	15	3
111			NA	NA
112				
113				
114	2			
115				
116				
117				
118	4	1		
119				
120	3	1		
121			NA	NA
Total units insp.	2500	500	2500	500
Tot. obs. made	52,500	10,500	2500	500
Unit P.A.	1.2%	1.2%	.6%	.6%
Obs. P.A.	.06%	.06%	.6%	.6%
Poorest ch. P.A.	.6%	.6%	.6%	.6%
Obs./Unit	21	21	1	1
Mh Rqd.	367.5	73.5	17.5	3.5
Minutes/Unit	8.2	8.2	.3	.3
Sec/Obs.	25.2	25.2	25.2	25.2

CHART 33

CHART 34

That's fine for the munitions commodity, but will the same principle apply where there are no clearly defined quality requirements? The answer is yes. This chart shows an assessment of the seriousness of observed defectiveness on 10 rough Terrain fork lift trucks based on the type of repair action needed to correct the deficiency. The theory behind this assessment was that maintenance and operator personnel could correct minor deficiencies but may not have the parts or the facilities necessary to correct the serious deficiencies. The assessment supported the QAR manning level revealed by a normal quality analysis. Shortly after this assessment was made, one of those hydraulic lines which operates between 6000-8000 PSI broke at a fitting. The whip action killed a company employee. So there was critical defectiveness even though none was observed on these units.

CHART 35

In addition to the normal quality analysis technique in Chicago, we have another analysis which can be properly defined as a profile analysis of PQA effort. We call this "QA performance cause and effects." While not directly related to the normal quality analysis, it does reveal some facts about our PQA effort that does support the normal quality analysis. Here you can see the September 1972 region performance data displayed as manhours per $1000 shipped. The regions are ranked based on the total MI (least to most). In this way it is relatively easy to analyze the cause of each region's rank position (the effect). It is also relatively easy to compare each region's expenditure of effort in each category to the National (CAS) average. Each abnormal variation can be considered as an effect, and motivates an analyst to go looking for causes. Here I would simply like to point out that the variation in the total manpower index between regions is matched by similar variations in product verification and administrative effort.

CHART 36

This chart displays the DCASR Chicago field activity data in the same manner as the previous chart did the National data. Here we see the same relative effect of the variation in product verification and administration along with a greater variation in system surveillance. Corrective action effort does not vary as the other types of effort does. But notice the system index here varies in a direction opposite to the other indexes. It would appear that as QARs became more proficient in performing PVI and systems surveillance, they expend a greater portion of their in-plant effort in obtaining corrective action. Isn't that the way PQAP is supposed to work? Why wasn't this phenomenon evident in the National data?

CHART 37

In April 1974 the same relationships continued but here we can see a slight decline in the amount of corrective action taken by some offices.

Defect Categorization for DCAS Final Vehicle
Inspection at Pettibone Mulliken
10 ea. Rough Terrain Fork Lift Truck Between Serial #1072-#1098

DEFECT	REPAIR ACTIONS: CRITICAL	REPAIR ACTIONS: SERIOUS	REPAIR ACTIONS: MINOR
	Safety hazards, missing guards, protective devices	Repair, replace, rework, reform	Tighten, reposition, adjust, clean
Hydraulic sys oil leaks		(replaced)- ///	(tightened)- ~~////~~ ~~////~~ ~~////~~ ////
Engine-drive-oil leaks		(replaced)- //	(tightened)- //
Engine won't idle			(adj.) - //
Controls out of adj.			(adj.) - ~~////~~
Loose parts			(tightened) - ///
Missing parts		(installed)-////	
Wrong parts		(installed)- /	
Hose chaffing		(replaced)- /	(reposition)- ///
Damaged fender		(straightened)- /	
Damaged stop		(rewelded) - /	
Moisture in light		(replaced) - /	
Void material in casting		(welded) - /	
Def. valve regulator		(replaced) - /	
Boom interference		(ground clearance) - //	
Def. operating instructions		(replaced) - //	(repositioned) - /
Dirt - excess oil			(cleaned) - /
Foreign material		(replaced unit) - /	(cleaned) - /
Sum Defects (58)	NONE	21	37
% of Sum		36.2%	63.8%
Defects observed Oct 71-Mar 72 (2425) (Prorated)		878	1,547
% of Total observations (36,895)		2.37	4.19%

CHART 34

CAS

QA PERFORMANCE CAUSE AND EFFECTS

Q 27b

SEPTEMBER 1972

ACTIVITY	PRODUCT VERIFICATION SAMPLE/NQ	PRODUCT VERIFICATION MH/$1000	SYS. SURV. MH/$1000	CORR ACT. MH/$1000	ADMIN. MH/$1000	SYSTEM INDEX	TOTAL MI MH/$1000
SAN FRANCISCO	2.48/1.51	.177	.037	.024	.132	9.90	.40
LOS ANGELES	.98/1.02	.168	.070	.015	.149	5.81	.42
BOSTON	.80/1.19	.199	.089	.027	.106	8.54	.43
ATLANTA	1.73/1.02	.192	.074	.019	.140	6.80	.45
DALLAS	.66/.81	.183	.077	.027	.154	9.44	.47
NEW YORK	.52/.95	.227	.056	.024	.152	7.83	.47
CAS	.90/1.00	.205	.077	.024	.148	7.79	.48
CHICAGO	.70/.92	.211	.081	.030	.139	9.28	.48
ST. LOUIS	.60/.91	.215	.074	.031	.173	9.78	.52
PHILADELPHIA	.74/.82	.242	.093	.017	.174	4.82	.55
CLEVELAND	.79/1.20	.296	.097	.038	.206	8.84	.68
DETROIT	1.59/1.66	.273	.146	.040	.234	8.65	.73

CHART 35

DCASR, CHICAGO

QA PERFORMANCE CAUSE AND EFFECTS

Q 27

DECEMBER 1972

ACTIVITY	PRODUCT VERIFICATION SAMPLE OI	PRODUCT VERIFICATION MH/$1000	SYS. SURV. MH/$1000	CORR ACT. MH/$1000	ADMIN. MH/$1000	SYSTEM INDEX	TOTAL MI MH/$1000
SOUTH BEND	12.12	.08	.02	.027	.05	20.17	.18
FT. WAYNE	1.49	.21	.07	.047	.10	14.43	.43
DELCO	4.25	.27	.01	.060	.10	17.51	.44
ROCKFORD	.71	.20	.08	.028	.15	9.27	.47
REGION	1.14	.23	.08	.032	.14	9.29	.51
MILWAUKEE	.84	.27	.09	.023	.13	6.12	.53
INDIANAPOLIS	.65	.29	.13	.031	.20	6.73	.70
CHICAGO OPNS.	.79	.35	.12	.033	.26	6.70	.81
NOV NATL. AVG.	1.06	.21	.07	.023	.14	7.51	.47

CHART 36

DCASR, CHICAGO

Q 27b

QA PERFORMANCE CAUSE AND EFFECTS

APRIL 1974

ACTIVITY	PRODUCT VERIFICATION % DEF.	PRODUCT VERIFICATION MH/$1000	SYS. SURV. MH/$1000	CORR. ACT. MH/$1000	ADMIN. MH/$1000	SYSTEM INDEX	TOTAL MI MH/$1000
SOUTH BEND	2.29	.113	.030	.028	.064	16.51	.244
ROCKFORD	.33	.132	.045	.034	.154	16.07	.387
CAS (March 74)	.96	.235	.070	.022	.134	6.77	.480
FORT WAYNE	3.36	.278	.051	.045	.143	12.03	.532
MILWAUKEE	.72	.300	.066	.021	.126	5.41	.536
REGION	.97	.284	.071	.030	.147	7.76	.555
INDIANAPOLIS	.36	.320	.088	.023	.146	5.31	.618
CHICAGO	1.28	.457	.123	.036	.246	5.82	.897

QA Activity Report

Mgmt. Analysis

CHART 37

CHART 38

In May 1977 we see that the variation still exists in PVI and administrative effort. Both show a decline in the intensity of effort which is probably related to inflation. We can see a slight increase in the intensity of systems surveillance effort. There is a very sharp decrease in corrective action effort, suggesting that we do not spend as much time obtaining corrective action for the deficiencies we see. This should be a matter of some concern.

CHART 39

This display of the National QA performance data in the cause and effect array reveals some new and very interesting factors. With only a few exceptions there is a significant uniformity in the amount of systems surveillance and other (administrative) effort emerging. Most of the variation in the overall performance index appears directly related to the performance of product verification inspection. This is the area where the normal quality analysis is designed to work. Now is the time for work to remove some of the stumbling blocks (biases if you will) and make the technique of normal quality analysis a more viable management tool.

CHART 40

Our plans and recommendations should help achieve that objective.

Is there a common denominator in procurement quality assurance? Does it tell you anything about the complexity of our mission or help describe how effective we are in accomplishing it?

Are there any questions?

Thank you!

DCASR, CHICAGO

QA PERFORMANCE CAUSE AND EFFECTS

MAY 1977

ACTIVITY	PRODUCT VERIFICATION % Def	MF/$1000	SYS.SURV. MH/$1000	CORR. ACT MH/$1000	OTHER MH/$1000	SYSTEM INDEX	TOTAL PI MH/$1000
DCASPRO ALLISON	1.50	.012	.007	.011	.071	35.94	.101
DCASMA SO. BEND	5.47	.079	.074	.015	.066	8.74	.234
NATIONAL AVERAGE	NA	.171	.074	.016	.122	6.13	.383
DCASR CHICAGO	1.08	.168	.080	.019	.121	7.30	.388
DCASMA MILWAUKEE	.51	.223	.100	.013	.116	3.95	.452
DCASMA FT. WAYNE	1.97	.207	.121	.046	.144	12.39	.518
DCASMA CHICAGO	.90	.278	.101	.024	.155	5.96	.558
DCASMA INDIANAPOLIS	1.31	.227	.098	.017	.244	4.95	.585
DCASPRO SUNDSTRAND	0.0	.307	.091	.036	.207	8.34	.641

CHART 38

DCASR, CHICAGO

QA PERFORMANCE CAUSE AND EFFECTS

MAY 1977

ACTIVITY	PRODUCT VERIFICATION % Def	PRODUCT VERIFICATION MH/$1000	SYS.SURV. MH/$1000	CORR.ACT. MH/$1000	OTHER MH/$1000	SYSTEM INDEX	TOTAL PI MH/$1000
ATLANTA	NA	.140	.080	.013	.107	5.58	.339
LOS ANGELES	NA	.151	.060	.016	.115	7.05	.342
ST LOUIS	NA	.163	.042	.016	.130	7.24	.351
DALLAS	NA	.130	.072	.017	.131	7.76	.351
BOSTON	NA	.162	.076	.014	.103	5.56	.355
NATIONAL AVG	NA	.171	.074	.016	.122	6.13	.383
CHICAGO	1.08	.168	.080	.019	.121	7.30	.388
PHILADELPHIA	NA	.196	.110	.014	.113	4.38	.434
CLEVELAND	NA	.214	.073	.026	.143	8.31	.456
NEW YORK	NA	.316	.086	.016	.203	3.83	.621

CHART 39

DCASR, CHICAGO

OR/EA SYMPOSIUM - JULY 1977

FUTURE ANALYTICAL EFFORTS (PLANNED)

- VALIDATE THE EXISTANCE OF INTEGRATED WORK COUNTS IN THE COMPOSITE OBSERVATION USING FOURIER INTEGRAL EVALUATION.

RECOMMENDED EFFORTS/ACTIONS

- REINSTATE THE SAMPLES INSPECTED WORKCOUNT IN THE RCS-448 AND NATIONAL MIR.
- COLLECT PRODUCT DEFECT INFORMATION (NOT PRODUCT DEFECTIVENESS) BY DEFECT CATEGORY, I.E., CRITICAL, MAJOR SERIOUS, MINOR.
- CONDUCT A STUDY TO DETERMINE IF THE NORMAL QUALITY COMMON DENOMINATORS ALSO OCCUR IN DEPOT/CENTER INSPECTION OPERATIONS.

CHART 40

DETERMINING OPTIMUM RESOURCE LEVELS IN PHYSICAL INVENTORIES

Captain Ronald H. Stokes

Introduction

DLA is presently spending large sums of money to remove errors from its records of stock on hand. In spite of this, it is evident that errors still exist and cause additional expense. This study was undertaken to determine the optimal amount of effort to spend removing record errors of stock on hand through physical inventories. The first subject discussed will be a description of the present situation and the development of a mathematical model to represent this environment. This will be followed by discussions on the assumptions made in developing the model, data collection and analysis, and, finally, some recommendations will be presented.

Background

In the DLA system, information on how much stock is stored at each depot is maintained at the Inventory Control Point (ICP). This information is used by the ICP to make many decisions such as when to order, how much to order, which depot to ship from, which depot to ship to, when to dispose of stock, how much to dispose of, when to backorder, etc. Each of these decisions is made so that costs will be minimized. If this information is inaccurate, the quality of the decisions is effected and costs increase. In an effort to reduce these increased costs, resources are expended to identify record errors and correct them. There are four separate programs which currently make most of the corrections to the ICP records. These programs are the physical inventory, locator reconciliation, Depot Balance and Transaction Register (DBTR), and denial research programs.

The physical inventory program schedules items to be counted based on the length of time since the last inventory and the category of the item. Some items must be counted every year; however, most items are divided into groups which are statistically sampled every three years. If more than a predetermined number of items have major errors ($500 or more), the entire group of items is inventoried.

The locator reconciliation program compares once a month the level of stock on record at the ICP with the locator files of the depot. A balance with no location or a location with no balance is considered a mismatch and an inventory is scheduled. Inventories can be taken any time during the succeeding month.

Normally however, only a portion of the mismatches are inventoried due to resource limitations.

The DBTR program is another monthly program which compares the ICP balance with the depot balance. Discrepancies are corrected by matching the corresponding records of each transaction which occurred during the preceding month. This program is the only one which does not look at the stock. It merely balances the bookkeeping functions between the ICP and depot. Consequently, it does not correct existing errors, but prevents some additional errors from occurring.

The last way in which errors are removed from the records is through the denial research program. A warehouse denial occurs when the ICP issues a release order which the depot cannot fill. Such denials cause the ICP to adjust its balance to zero.

The locator reconciliation, DBTR, and denial research programs correct record errors when an indication of an error is received. The locator reconciliation and denial research programs tend to correct records when the on hand balance is relatively low, but the procurement cycle during which these corrections occur is unpredictable. The DBTR program corrects errors at any point during the procurement cycle and can be viewed as merely reducing the probability of an error on each transaction.

Besides the programs which correct errors, the other aspect of the system to be modeled is the propogation of the errors themselves. This aspect is not as concrete as the error correcting programs, but some general comments can be made. The most obvious observation is that since the size of the error is unknown, it must be described by a probability distribution. This distribution gives the probability of having no error, one more item than is on record, one less item than is on record, etc. as illustrated in figure I. Furthermore, it is reasonable to assume that if the ICP and depot conduct business for a period of time without the records of stock on hand being corrected, the probability of having an error in the records and the average size of the error will increase.

Although the record error is unknown, information is gained about its possible value each procurement cycle even though no denial or locator reconciliation mismatch occurs. This phenomenon occurs because it is impossible to overstate the actual quantity on hand by more than the recorded stock on hand. This limit is most confining just prior to a receipt. Thus, at the beginning of the procurement cycle the expected error might be relatively symmetric, but when no denial has occurred by the time a new procurement arrives, we must adjust our previous estimate to include this new information as illustrated in figure II.

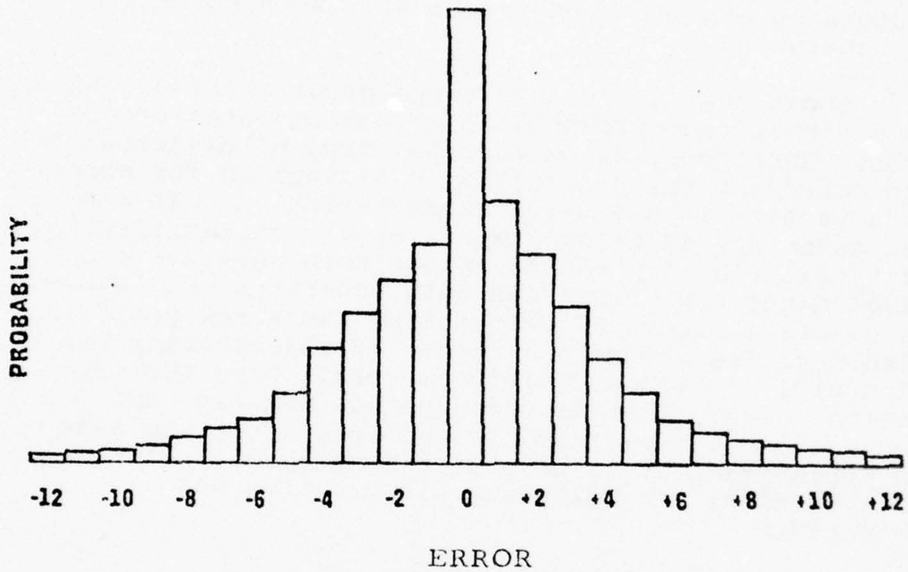


FIGURE I

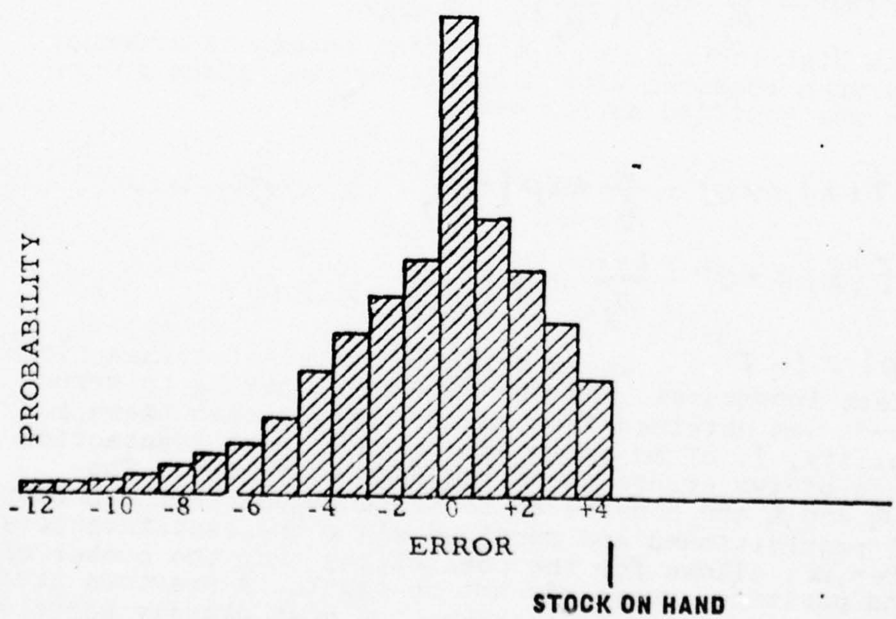


FIGURE II

Thus, although the error of understating the stock balance can grow from procurement cycle to procurement cycle, the error of having less stock on hand than on record will tend to trigger a denial and be corrected.

Experience has shown that there is a large probability of having no error and a significant probability of having large errors in the records. Therefore, an exponential type of distribution was chosen to represent the probability distribution for errors in the records because it has these characteristics. It also has the added advantage of being easy to handle mathematically. The probability distribution has to handle both negative and positive values since the errors can both understate and overstate actual assets. Errors of overstating the stock position will be called negative errors and errors of understating the stock position will be called positive errors. From the previous discussion, however, it is obvious that negative and positive errors are not propogated in the records in the same fashion from procurement cycle to procurement cycle. With these criteria in mind, the following distribution was initially selected:

$$f(x) = \frac{\alpha}{\beta_1} \exp\left(\frac{X}{\beta_1}\right), \qquad X < 0$$

$$f(x) = \frac{1-\alpha}{\beta_g} \exp\left(\frac{-X}{\beta_g}\right), \qquad X \geq 0$$

However, this distribution did not predict enough occurrences of no errors when compared with a sample of real items so the distribution was modified as follows:

$$f(X \mid X \neq 0) = \frac{\alpha}{\beta_1} \exp\left(\frac{X}{\beta_1}\right), \qquad X < 0$$

$$f(X \mid X \neq 0) = \frac{1-\alpha}{\beta_g} \exp\left(\frac{-X}{\beta_g}\right), \qquad X > 0$$

$Prob(X \neq 0) = 1 - T^N$ where N is the number of transactions since the last inventory. The probability of having an error in the records was obtained from the assumption that there is some probability, T, of an error occurring on each transaction and no chance of two errors canceling each other out. The parameters β_1 and β_g are considered to be functions of the amount of materiel requisitioned and received since the last inventory. The parameter, α, allows for the possibility that the number of negative and positive errors may not be equal. A previous study found that the probability of an error was most closely correlated with the number of requisitions and receipts while the size of the error was most closely correlated with amount requisitioned and received.

Before expressions for costs can be developed, an inventory policy must be chosen. The first policy decision which must be made is whether to use a trigger policy or a calendar policy. A trigger policy uses the fact that accurate asset information is more important at certain points of the procurement cycle than at others. The two most important times during the procurement cycle to have accurate information is just prior to placing an order and just prior to the receipt of a shipment. Asset information is used in placing orders to minimize the sum of holding costs and backorder costs. Ordering early will increase holding costs more than it will decrease backorder costs, and ordering late will increase backorder costs more than it will decrease holding costs. Asset information is used just prior to the receipt of a shipment in making backorder decisions. If the ICP does not have enough assets on record to satisfy a requisition, the requisition is backordered. However, if the assets were understated and there were, in fact, enough assets to fill the requisition, the error will lead to unnecessary backorder and holding costs. A calendar policy schedules inventories based on the elapsed time since the last inventory without regard to asset position. This policy may have the advantage of being easier to implement. Since SAMMS maintains a perpetual inventory, it was decided that the advantages of a trigger policy would probably outweigh the added difficulty in implementation. A previous study* indicated that the increased costs from faulty information was greater before receipt of a shipment than before placing an order. Therefore, a trigger policy of inventorying stock prior to receipt of a shipment was selected.

The other inventory policy decision which must be made is whether to use a sample inventory or a full count inventory. The sample inventory is taken to get an improved estimate of the record accuracy of the items in the group. This technique is most efficient when the sampled group is as homogeneous as possible with respect to the probability of having an error in the records. Presently the items are grouped by supply class and not by any tendency toward errors. Therefore, making β_1 and β_9 functions of amount shipped and received would probably be as effective in estimating record accuracy as a sample inventory. A further consideration is that the sample inventory technique does not combine well with a trigger policy. Therefore, a full count inventory policy was chosen.

Development of Mathematical Model

Since we have already decided to inventory all of the stock before receipt of a new procurement, the only decision left is the number of procurement cycles between inventories. This is calculated by computing the expected cost per procurement

* Physical Inventory Decision Model, P. 49

cycle for different numbers of procurement cycles between inventories.

Everything is now set for the calculation of expected costs per procurement cycle. The inventory policy states that the stock will be inventoried when procurement cycles have elapsed since the last inventory. The number of procurement cycles since the last inventory can be considered a state or condition of an item. The expected costs for a specific state must be weighted by the probability of being in that state. If there were no unscheduled inventories, each state would be equally likely. However, warehouse denials and locator reconciliation inventories cause the state of the system to revert back to one (n=1). This phenomenon can be modeled as a Markov Chain. The transition matrix, P, is of the form

$$P = \begin{bmatrix} Pd_1 & 1-Pd_1 & 0 & \cdots & 0 \\ Pd_2 & 0 & 1-Pd_2 & \cdots & 0 \\ Pd_3 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ Pd_{n-1} & 0 & 0 & \cdots & 1-Pd_{n-1} \\ 1 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

where Pd_X is the probability of experiencing a denial or locator reconciliation inventory X procurement cycles after an inventory. Thus, if an item is in state X, the probability of going to state one during the next procurement cycle is Pd_X and the probability of going to state X + 1 is $1 - Pd_X$. This holds unless the item is in state n, in which case the probability of going to state one during the next procurement cycle is one. A vector which gives the probability of being in each of the states at a specific time is known as a state vector. For example, if

$\Pi_i = (\pi_{1i}, \pi_{2i}, \cdots, \pi_{ni})$ is the state vector for cycle i, the probability of being in state 1 is π_{1i}, the probability of being in state 2 is π_{2i}, etc. The state vector for cycle i + 1 (Π_{i+1}) is then given by

$$(\pi_{1\,i+1}, \pi_{2\,i+1}, \ldots, \pi_{n\,i+1}) = (\pi_{1i}, \pi_{2i}, \ldots, \pi_{ni}) \begin{bmatrix} Pd_1 & 1-Pd_1 & 0 & \cdots & 0 \\ Pd_2 & 0 & 1-Pd_2 & \cdots & 0 \\ Pd_3 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ Pd_{n-1} & 0 & 0 & \cdots & 1-Pd_{n-1} \\ 1 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

No matter which state the system starts out in, the probability of being in a particular state should be nearly a constant after the system has existed for a long period of time. These steady state probabilities can be obtained by solving this system of equations:

$$(\pi_1, \pi_2, \ldots, \pi_n) = (\pi_1, \pi_2, \ldots, \pi_n)\, P$$

plus the additional constraint $\pi_1 + \pi_2 + \cdots + \pi_n = 1$

$$\Rightarrow \quad Pd_1\,\pi_1 + Pd_2\,\pi_2 + \ldots + \pi_n = \pi_1$$

$$(1 - Pd_1)\,\pi_1 = \pi_2$$

$$(1 - Pd_2)\,\pi_2 = \pi_3$$

$$\vdots \qquad\qquad \vdots$$

$$(1 - Pd_{n-1})\,\pi_{n-1} = \pi_n$$

$$\pi_1 + \pi_2 + \cdots + \pi_n = 1$$

$$\Rightarrow \pi_1 + (1-Pd_1)\pi_1 + (1-Pd_1)(1-Pd_2)\pi_1 + \ldots + (1-Pd_1)(1-Pd_2)\ldots(1-Pd_{n-1})\pi_1 = 1$$

$$\Rightarrow \pi_1 = 1/[1 + (1-Pd_1) + (1-Pd_1)(1-Pd_2) + \ldots + (1-Pd_1)(1-Pd_2)\ldots(1-Pd_{n-1})]$$

$$\pi_2 = (1-Pd_1)/[1 + (1-Pd_1) + (1-Pd_1)(1-Pd_2) + \ldots + (1-Pd_1)(1-Pd_2)\ldots(1-Pd_{n-1})]$$

$$\vdots \qquad\qquad \vdots$$

$$\pi_n = (1-Pd_1)(1-Pd_2)\ldots(1-Pd_{n-1})/[1 + (1-Pd_1) + (1-Pd_1)(1-Pd_2) + \ldots + (1-Pd_1)(1-Pd_2)\ldots(1-Pd_{n-1})]$$

Since this is a very complicated expression, it was assumed that the probability of a denial or locator reconciliation inventory is the same for every procurement cycle ($Pd_1 = Pd_2 = \ldots = Pd_n$). This implies that the distribution for negative errors is the same for every procurement cycle. This is not exactly true. However, it serves as a first order approximation of the information gained from the lack of a denial. The state probabilities are then given by

$$\pi_1 = 1/[1 + (1-P) + (1-P)^2 + \ldots + (1-P)^{n-1}] = 1/\sum_{k=0}^{n-1} (1-P)^k$$

$$\sum_{k=0}^{n-1} (1-P)^k = [1 - (1-P)^n]/P$$

$$\Rightarrow \pi_1 = P/[1 - (1-P)^n]$$

$$\vdots \qquad \vdots$$

$$\pi_n = (1-P)^{n-1} P/[1 - (1-P)^n]$$

To determine P, the probability of a denial and locator reconciliation inventory must be determined. The probability of a denial is the probability that demands plus error is greater than the mean leadtime demand plus safety level while the demands themselves are less than or equal to the mean leadtime demand plus safety level:

$$\text{Prob}\ (X + Y > u + SL \mid X \leq u + SL)$$

X - demands
Y - error
u = mean leadtime demand
SL = safety level

The distribution of demand plus error is given by the convolution of the distribution of demands and the distribution of error. The distribution of demands is:

$$f(x) = \frac{\sqrt{2}}{2\sigma} \exp\left(-\sqrt{2}\left|\frac{x-u}{\sigma}\right|\right)^*$$

where u = mean leadtime demand
σ = standard deviation of demand over leadtime

The distribution of error is the portion of the error distribution for positive errors: $f(y) = \frac{(\alpha)(1-T^N)}{\beta_1} \exp\left(\frac{-y}{\beta_1}\right)$

where N = number of requisitions and receipts per procurement cycle. The distribution desired is the distribution of Z = X - Y = X + (-Y) . The distribution of - Y is f(-Y) $= \frac{\alpha(1-T^N)}{\beta_1}\exp\left(\frac{Y}{\beta_1}\right), Y>0.$ Thus the distribution of demand plus error, given demand is less than or equal to mean leadtime demand plus safety level, is:

$$g(z) = \int_0^{u+SL} \frac{(\alpha)(1-T^N)}{\beta_1} \exp\left(\frac{-(z-x)}{\beta_1}\right) \frac{\sqrt{2}}{2\sigma} \exp\left(-\sqrt{2}\left|\frac{x-u}{\sigma}\right|\right) dx$$

$$= \frac{\alpha\sqrt{2}(1-T^N)}{2(\sigma+\sqrt{2}\beta_1)}\left[\exp\left(\frac{u-z}{\beta_1}\right) - \exp\left(\frac{-\sqrt{2}\beta_1 u - \sigma z}{}\right)\right]$$

$$+ \frac{\alpha\sqrt{2}(1-T^N)}{2(\sigma-\sqrt{2}\beta_1)}\left[\exp\left(\frac{\sigma(u+SL)-\sqrt{2}\beta_1 SL - \sigma z}{\sigma\beta_1}\right) - \exp\left(\frac{u-z}{\beta_1}\right)\right]$$

The probability of a denial is then the probability that the convolution of demands plus error is greater than mean leadtime demand plus safety level.

$$\text{Prob (denial)} = \int_{u+SL}^{\infty} g(z)\,dz$$

$$= \frac{\sqrt{2}\beta_1\alpha(1-T^N)}{2(\sigma+\sqrt{2}\beta_1)}\left[\exp\left(\frac{-SL}{\beta_1}\right) - \exp\left(\frac{-\sqrt{2}\beta_1 u - \sigma u - \sigma SL}{\sigma\beta_1}\right)\right]$$

*HQ DLA Guidance for Implementation of Time-weighted Essentially-weighted Requisitions Short Variable Safety Level.

$$+ \frac{\sqrt{2}\beta_1\alpha(1-T^N)}{2(\sigma-\sqrt{2}\beta_1)}\left[\exp\left(\frac{-\sqrt{2}\,SL}{\sigma}\right)-\exp\left(\frac{-SL}{\beta_1}\right)\right]$$

The probability of a locator reconciliation inventory would be much more difficult to calculate from item characteristics. As mentioned earlier, inventories can be triggered by either of two kinds of mismatches, balance - no location or location - no balance. The probability of being in either of these positions when the locator reconciliation program is run would be difficult to calculate. These mismatches can also be caused by the failure to cancel a location or the canceling of a wrong location. Even after the mismatches are determined, only a portion are normally inventoried and this depends on the workload in other areas as well as the number of mismatches.

Because of all these complications, the probability of a locator reconciliation inventory was estimated by dividing the number of locator reconciliation inventories during a thirteen-month period by the number of receipts due to new procurements. The value used as the probability of an unscheduled inventory is then the sum of the probability of a denial and the probability of a location reconciliation inventory.

The costs included in the model are holding, denial, backorder, and inventory costs. The number of backorders experienced in a procurement cycle are effected by both negative and positive errors. Negative errors (overstating the stock position) cause the procurement to be made late which leads to increased probabilities of backorders and warehouse denials. Since we have already decided to inventory before the receipt of a new procurement, the inventory occurs too late to prevent late buys. Therefore, no effect from the inventory will be noticed during the procurement cycle in which the inventory is taken. Also, since we have assumed that the probability and size of negative errors do not change from procurement cycle to procurement cycle, the increase in backorders does not change from procurement cycle to procurement cycle. Therefore, the effect of increased backorders due to late procurements is unaffected by the number of procurement cycles between inventories and can be left out of the model.

The probability and size of positive errors (understating the stock position) do change from procurement cycle to procurement cycle, however. The size of the positive error does not effect backorders, though, unless an inventory is taken. Otherwise, the ICP will backorder requisitions, not knowing that the assets are available at the depot. During the procurement cycle in which the stock is inventoried, however, backorders are reduced. The effect of inventorying an item with a positive error is the same

as increasing the reorder point or safety level.

The expected backorders when ordering at a greater asset position than the reorder point is computed as follows:

$$E(BO|Y) = \frac{1}{QS}\int_{r+Y}^{\infty}(x-r-Y)\frac{1}{2}\left(1-\exp\left(\frac{-\sqrt{2}\,Q}{\sigma}\right)\right)\exp\left(\frac{-\sqrt{2}(x-u)}{\sigma}\right)dx$$

$$= \sigma^2\left(1-\exp\left(\frac{-\sqrt{2}\,Q}{\sigma}\right)\right)\exp\left(-\sqrt{2}\left(\frac{SL+Y}{\sigma}\right)\right)\Big/4QS$$

where the reorder point is r. This computation is the same as the one contained in the computation of expected backorders for the variable safety level. The expected backorders when stock position is understated is computed by integrating over all positive errors, i.e.:

$$E(BO) = \int_0^{\infty}\frac{(1-\alpha)(1-T^M)}{\beta_g}\exp\left(\frac{-Y}{\beta_g}\right)\frac{\sigma^2\left(1-\exp\left(\frac{-\sqrt{2}\,Q}{\sigma}\right)\right)}{4QS}\exp\left(-\sqrt{2}\left(\frac{SL+Y}{\sigma}\right)\right)dY$$

$$= (1-\alpha)(1-T^M)\,\sigma^3\left(1-\exp\left(\frac{-\sqrt{2}\,Q}{\sigma}\right)\right)\exp\left(\frac{-\sqrt{2}\,SL}{\sigma}\right)\Big/4QS(\sqrt{2}\beta_g+\sigma)$$

where M = requisitions and receipts since last inventory
Q = order quantity
S = average requisition quantity.

Thus, inventorying an item results in savings due to decreased backorders in the procurement cycle in which the inventory is taken. The amount of savings is the difference between the expected backorders when a positive error exists and the expected backorders when no error exists integrated over all possible errors and is realized during the procurement cycle in which the inventory is taken.

Holding cost is another cost included in the mathematical model. Since the probability distribution for negative errors is assumed constant from procurement cycle to procurement cycle, the decreased holding costs due to overstating the stock position is independent of how often the item is inventoried and can be ignored. The increased holding costs due to understating the stock position, however, tend to grow and are greatest in the procurement cycle in which the inventory is taken. The increase in stock due to positive errors is given by:

$$\int_0^{\infty} Y(1-\alpha)(1-T^M)\exp\left(\frac{-Y}{\beta_g}\right)dY$$

$$= (\beta_g)(1-\alpha)(1-T^M)$$

The increase in holding cost is obtained by multiplying by the unit price, holding cost rate, and years per procurement cycle.

$$= \beta_g(1-\alpha)(1-T^M)\,a\,c\,Q/AD$$

where AD = annual demand

a = holding cost rate

c = unit price.

Since the holding costs vary from procurement cycle to procurement cycle, this cost must be multiplied by the probability of being in a particular state. Thus, the total increase in holding cost incurred under a policy of inventorying an item every n cycles is:

$$\frac{(1-\alpha)\,ac\,PQ}{AD(1-(1-P)^n)} \sum_{i=1}^{n} (1-P)^{i-1}\left(1-T^{i(\frac{Q}{S}+1)}\right)\beta_g$$

where $\frac{Q}{S}+1$ = number of requisitions and receipts per procurement cycle.

βg is left in the summation because it varies from procurement cycle to procurement cycle.

The total cost expression is then:

$$K = \frac{P(1-P)^{n-1}}{1-(1-P)^n}\left[C_d(P-G)+C_i+\frac{(1-\alpha)(1-T^M)\sigma ac}{\sqrt{2}}\left(\frac{\sigma}{\sqrt{2}\beta_g+\sigma}-1\right)\right]$$

$$+\frac{(1-\alpha)\,ac\,PQ}{AD(1-(1-P)^n)} \sum_{i=1}^{n} (1-P)^{i-1}\left(1-T^{i(\frac{Q}{S}+1)}\right)\beta_g$$

Where C_d = cost of processing a warehouse denial,

C_1 = cost of inventorying stock,

G = probability of a location reconciliation inventory,

and

$$P=\frac{\sqrt{2}\beta_1\alpha(1-T^M)}{2(\sigma+\sqrt{2}\beta_1)}\left[\exp\left(-\frac{SL}{\beta_1}\right)-\exp\left(\frac{-\sqrt{2}\beta_1 u-\sigma u-\sigma SL}{\sigma\beta_1}\right)\right]$$

$$+\frac{\sqrt{2}\beta_1\alpha(1-T^M)}{2(\sigma-\sqrt{2}\beta_1)}\left[\exp\left(\frac{-\sqrt{2}\,SL}{\sigma}\right)-\exp\left(\frac{-SL}{\beta_1}\right)\right]+G.$$

Assumptions

It can be seen that the whole system of correcting errors, generating errors, and the associated costs is very complicated. In developing the mathematical model of the system, an attempt was made to include all significant costs. Naturally, many costs and aspects of this system had to be ignored. Although many of the costs which were ignored and other assumptions used in developing the model are obvious, they should be stated because of their importance.

Probably the most obvious assumption is that the probability distribution of negative errors does not change from procurement cycle to procurement cycle. This assumption not only simplifies the computation of being in a particular state but greatly simplifies the computation of backorder, holding and denial costs. Partial justification for this assumption will be provided in the discussion on data collection and analysis.

Another major assumption is that each ICP uses only one depot to store its stock. This simplification means that the increased costs due to misallocating stocks among the depots is not considered. It also means that denial costs do not include delays in processing MROs. These occur when the depot searches for an item for a period of time and then denies it while another depot has the stock. This assumption also affects the calculation of backorder costs.

Other assumptions which were made in developing the math model include:

(1) increased procurement costs are negligible.

(2) increased disposal costs are negligible.

(3) the effect of control levels is negligible.

(4) errors are distributed with an exponential type distribution.

(5) denials can be eliminated during the procurement cycle in which the item is inventoried.

This last assumption is included in the model by counting the denial costs as a savings in the inventoried procurement cycle.

Data Collection and Analysis

Now that the mathematical model of the inventory system has been developed, the parameters of the distribution for record errors must be estimated. The data used to estimate these parameters was obtained from 24 months of history on 317 items. The number

of transactions and receipts were recorded between inventories or between denials and inventories. Also, the amount received and requisitioned and the gains and losses were recorded. These 317 items provided 386 observations of which 110 were gains, 88 were losses and 188 had no adjustments.

The probability of not having an error on a transaction, T, was estimated by minimizing the expression

$$\sum_{i=1}^{386} (T^{q_i} - r_i)$$

where q_i = number of transactions

$$r_i = \begin{cases} 1, \text{if there was no adjustment} \\ 0, \text{if there was an adjustment} \end{cases}$$

i = the index of observations from the sample.

$\sum_{i=1}^{386} (T^{q_i} - r_i)^2$ is the sum of squares between the predicted probability of error and whether the item actually experienced an error. The estimated value of T was .9477.

The zero adjustments were then proportioned among the gains and losses and regression analysis was used to estimate β_g and β_l. The regression to determine β_g was between gains and the average of amount requisitioned and amount received, and is given by:

$$\beta_g = 19.1642 + .022(R)$$

where R = average of amount requisitioned and amount received.

The regression to determine β_l was between losses and the average of amount requisitioned and amount received divided by number of receipts plus 1, and is given by:

$$\beta_l = 25.4617 + .0486\left(\frac{R}{r + 1}\right)$$

where r = number of receipts from new procurements.

The average of amount requisitioned and amount received divided by number of receipts plus 1 was used to estimate the amount of activity per procurement cycle.

It was significant that the correlation between losses, and average of quantity received and requisitioned per procurement cycle is greater than the correlation between losses, and

average of total quantity received and requisitioned. This serves as partial justification for assuming that the probability distribution does not change from procurement cycle to procurement cycle since it is more useful to know the amount received and requisitioned per procurement cycle than to know the total amount received and requisitioned in estimating the probability distribution of the inventory losses (negative error).

The probability distribution to be used in the model then becomes:

$$f(x|x\neq 0) = \frac{.4335(1-.9477^{Q})}{25.4617+.0486Q}\exp\left(\frac{-X}{25.4617+.0486Q}\right) \qquad X>0$$

$$= \frac{.5665(1-.9477^{iQ})}{19.1642+.0221Q}\exp\left(\frac{X}{19.1642+.0221Q}\right) \qquad X<0$$

where Q = order quantity

i = number of procurement cycles since the last inventory.

This distribution was then tested with the sample for goodness of fit. The distribution failed the Chi-square goodness of fit test. However, a graph of the errors predicted by the distribution and those experienced by the sample show good agreement for no errors and for large errors as illustrated in figure III. Since these are the most significant regions, use of the distribution will probably not bias the results significantly.

Results

The mathematical model was solved by the method of forward differences. The model is assumed to be concave, so the number of procurement cycles between inventories is incremented by one until the cost increases. As it turns out, this is an efficient method of optimizing the model due to the large number of cases in which the optimal solution is to inventory every procurement cycle. Also, most of the computations do not have to be repeated when n is incremented. This optimization is done for many sets of parameters in the model so that a matrix is formed. The optimal number of procurement cycles between inventories for a particular item is then determined from a table lookup routine.

Results from the math model indicate that the number of inventories which will be required will increase. Due to the reluctance to assign additional resources to support functions such as physical inventory and due to the many assumptions involved in developing the math model, it was felt that a simulation should be used to verify the robustness of some of the assumptions.

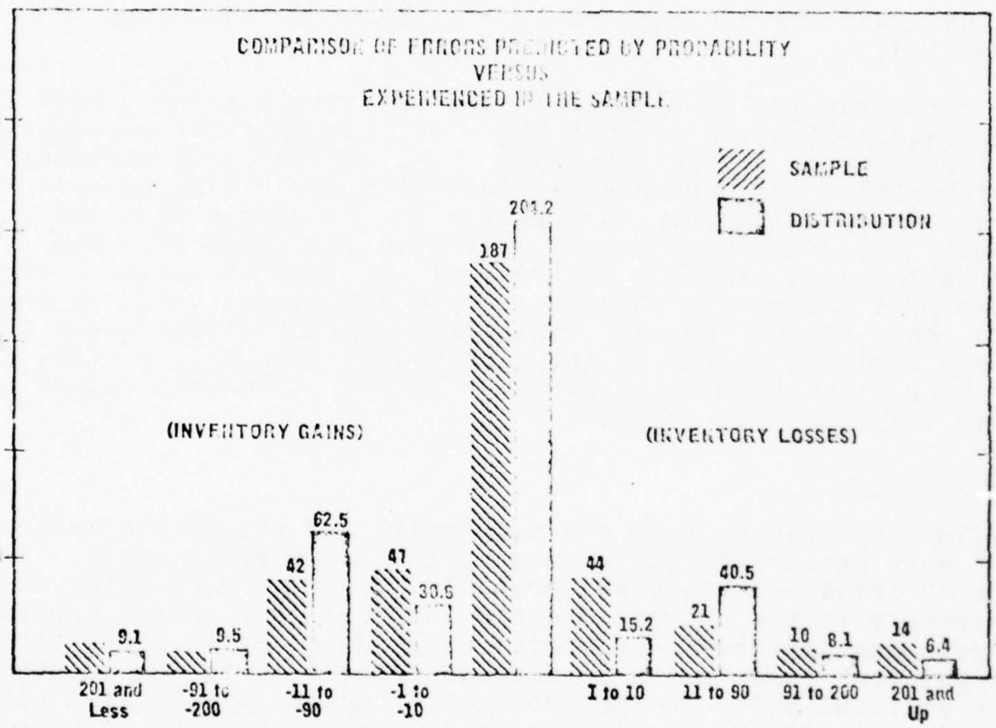

COMPARISON OF ERRORS PREDICTED BY PROBABILITY
VERSUS
EXPERIENCED IN THE SAMPLE
250
200
150
50
SAMPLE
DISTRIBUTION
(INVENTORY GAINS)
(INVENTORY LOSSES)
9.1
9.5
42
62.5
47
187
44
15.2
21
40.5
10
8.1
14
6.4
201 and Less
-91 to -200
-11 to -90
-1 to -10
1 to 10
11 to 90
91 to 200
201 and Up

FIGURE III

The simulation is closer to the real world because of the following properties:

(1) no assumption is made about the probability distribution for negative errors not changing from procurement cycle to procurement cycle.

(2) procurement costs are included.

(3) the exponential type of distribution is not used.

(4) denials can occur before or after an inventory is conducted.

The error generating process in the simulation assumes that for each requisition and receipt there is a probability of error which is a percentage of the requisition and receipt. By choosing the probabilities and percentages, the error generating process produced errors which were much closer to the sample than the probability distribution as illustrated in figure IV. The simulation simulates the activity of one item at a time. Six items were chosen for modeling in the simulation based on their wide range of unit prices. This item characteristic seems to be the dominant factor in the math model. Results, so far, from the simulation tend to support the optimal inventory policy derived from the math model.

Conclusion

Preliminary results from the math model and simulation indicate that more resources should be used in inventorying stock. The current level of effort was probably set without relating it concretely to the increased costs incurred from record errors. By relating physical inventories to reduced costs and by timing the physical inventories so that accurate records can be obtained at a critical point in the procurement cycle, substantial savings should be realized. Therefore, based on the results of this study, I anticipate recommending a trigger policy for physical inventories with a predetermined number of procurement cycles between inventories.

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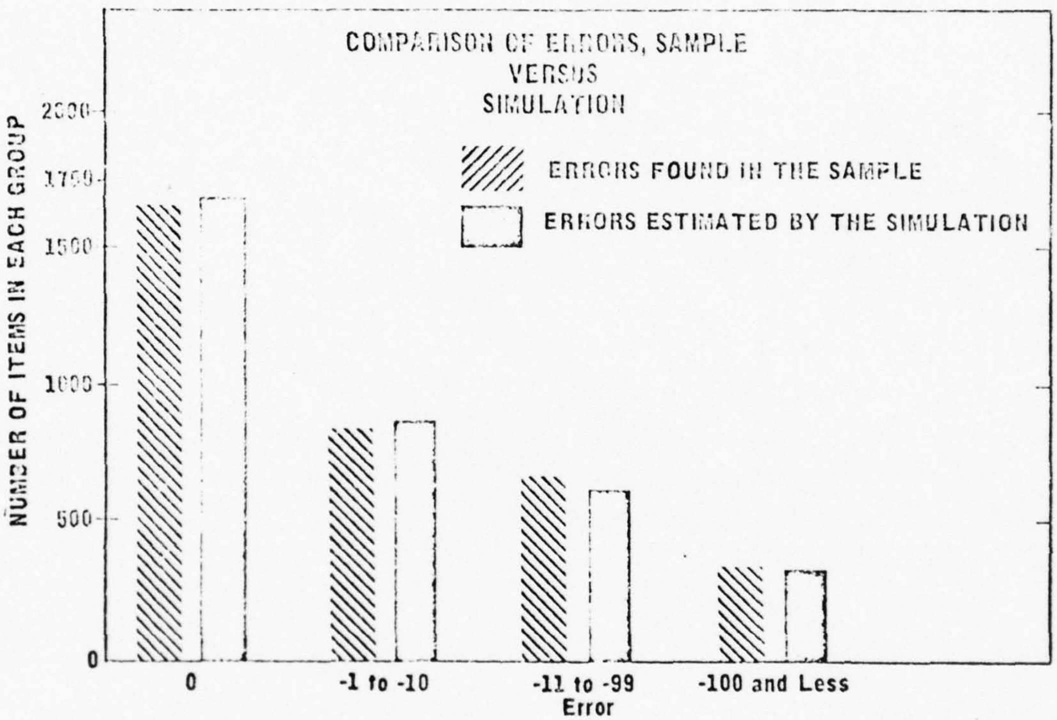


COMPARISON OF ERRORS, SAMPLE
VERSUS
SIMULATION
ERRORS FOUND IN THE SAMPLE
ERRORS ESTIMATED BY THE SIMULATION
NUMBER OF ITEMS IN EACH GROUP
2000
1750
1500
1000
500
0
0
-1 to -10
-11 to -99
-100 and Less
Error

FIGURE IV

AN ANALYSIS OF THE SUBSISTENCE
QUALITY SYSTEMS AUDIT PROGRAM

by Major John Caso

I. INTRODUCTION

The purpose of this analysis was to evaluate the effectiveness of the Defense Logistics Agency (DLA) Quality Systems Audit Program (QSAP) and to investigate recommendations for improvement of the program if appropriate.

DLA Regulation 4155.2, "Quality Systems Audit Program," defines the purpose of the program in paragraph III. "QSAP is a HQ DLA directed program developed to provide timely management information on the quality of items entering the DLA supply system. Through its systems audit techniques, QSAP will provide management a means of determining and evaluating the effectiveness of the DLA Quality and Reliability Assurance Program."

The actual analysis in this paper involved little investigation into the actual mechanics of the current QSAP but rather focused efforts to determine what the requirements of such a program would be to successfully achieve the stated objective.

The requirements determined by this analysis were stated in purely statistical terms and little consideration was given to subjective benefits which were not quantifiable.

While specific comments and subsequent recommendations were directed toward the QSAP for the Subsistence Commodity, the recommendations could be applied to other commodities QSAP's with slight modifications. Additionally, an attempt was made to expand discussion of certain aspects of the origin and audit inspection processes to provide clarification of these aspects to interested individuals who are not statistically oriented. This explanation will hopefully prove to be a beneficial secondary purpose of this paper. Statistics and mathematical formulations of a more complicated nature are included as appendices to this paper for the interested reader but are not necessary for a basic understanding of the recommendations.

II. PRESENT SUBSISTENCE QSAP

The objectives of the QSAP as defined by DLAR 4155.2 are further defined in the standard operating procedures. Sec. 3.2.2 states that "the DLA Quality Audit was established to provide a measure of the quality effectiveness of the total DLA procurement operation." To use this measure as a management tool we must have some relative degree of confidence in the measure. The measure, as defined, should be a statistically accurate estimate of the quality of material entering our system. In other words; how much nonconforming material is getting by the origin inspection process?

Table 1 presents a breakdown of subsistence items into relatively homogeneous groups with respect to the inspection processes involved.

The chart indicates that only three of the ten groupings of perishable subsistence items are currently being audited. This fact by itself may not be a problem if a determination had been made that these three groups were the only ones of interest.

Table 2 presents a summary of nonperishable audits for the July through September time period.

A review of the data of Tables 1, 2 and 3 provides positive indication that the subsistence quality audit program is not meeting the defined objective. The sample sizes are too small when matched against the groupings of Table 1 - and the coverage of the sample selections does not appear to be broad enough to insure a random sample. The apparent lack of a systematic approach to accurately estimate the quality of the material entering the system is evidenced by the noticeable absence of any such estimate. In other words, no management action can be confidently based on the results of the information which is provided.

The problem also appears to be compounded by the use of the QSAP to effect warranty actions. The program does not appear to have been designed for this purpose. Rather it was instituted as a check on the origin inspection process. The efforts associated with these warranty actions, such as special audits, do not appear to be justified in terms of the value returned from the warranty process. These special audits also have a deleterious effect of diverting audit inspection resources from the primary objective.

At the present time it does not appear that the QSAP is effective in meeting the defined objectives of the program. The only possible beneficial effect arises simply as a result of the existance of the program. The fact that both the vendors and origin inspectors realize that some additional check could be made will provide some positive benefits. There does not exist, however, any statistically accurate estimate of the quality of material which could be used as a basis for management actions.

The remainder of this paper is performed assuming that the above stated premise is true. The following sections will provide a theoretical basis for establishment of a system that will meet the defined objective and the appropriate recommendations for implementation of this system to the subsistence environment.

III. VENDOR PHILOSOPHY

In order to estimate the exact nature of the quality of goods entering the supply system, it is necessary to have some idea of the quality of goods being presented for origin inspection. This is also necessary to accurately evaluate the performance of the origin inspection process itself. An important example to keep in mind throughout the remainder of

TABLE 1

SUBSISTENCE GROUPS AND SUB-GROUPS

PERISHABLES

CHILLED	FROZEN	
Fruits and Vegetables	Fruits and Vegetables	
Meats (Red)	Meats (Red)	1/
Poultry	Poultry	1/
Seafood	Seafood	1/
Dairy	Dairy	

NONPERISHABLES 2/

FRUITS AND VEGETABLES	FARINACEOUS	MEATS	CONDIMENTS
Canned	Canned	Canned	Canned
Dried (Bagged or Boxed)	Bagged or Boxed		Dry (Bagged or Boxed)

1/ Perishables being audited.

2/ All nonperishable are susceptible to being audited. Most performed on Fruits, Vegetables and Farinaceous products.

SOURCE: DPSC-ST

TABLE 2

NONPERISHABLE AUDITS 1 JULY 76 - 30 SEPTEMBER 76

	JUL	AUG	SEP	AVG.	ANNUAL*
Mechanicsburg	9	6	6	7	84
Memphis	11	8	14	11	132
Tracy	4	3	3	3.3	40
TOTALS	24	17	23	21.3	256

* Estimate Projected from July - September data.

TABLE 3

PERISHABLE AUDITS 1 JULY 76 - 30 SEPTEMBER 76

	JULY	AUG	SEP
Fort Bragg	6	6	-
Fort Carson	4	7	2
Fort Lewis	12	12	12
Fort Campbell	8	2	-
Fort Hood	0	**	**
Fort Ord	2	3	3
Kansas City	1	1	4
Bayonne	-	1	5
NSC Norfolk	-	-	9
TOTALS	33	32	35

Average per month 33.3 Annual *400

** Discounted as audit site

* Estimate projected from July - September data.

this paper is the following: Suppose an acceptance sampling plan is designed to accept lots which are "bad" 10% of the time. If the vendor presents material which is bad 50% of the time, then 5% (.1)X(.5) would get through. Audit inspection would show a 5% rate of nonconforming material entering the system. Similarly, if another vendor presents "bad" material 10% of the time, the audit would only indicate a 1% rate of nonconforming material entering the system. Both inspectors would be performing their function in exactly the same manner and should be rated equally.

Exactly why bad material is ever accepted and the need for sampling will be discussed later.

We will assume that the vendor is basically an honest person in business to maximize profit on both a long and short run basis. Consider a vendor who is in constant business with the government. Over a period of time many lots or batches of his product will be presented for inspection. The vendor is aware of our acceptance sampling plan and has been given an acceptable quality level (AQL) to comply with respect to the product being supplied. The effect of using a sampling plan for acceptance inspection is in general to force the vendor to submit product of such a quality that a small percentage of submitted inspection lots is rejected. If he submits products of very low quality, many inspection lots are rejected. If he submits product of extremely high quality, he may be incurring higher production costs than are necessary in order that the great bulk of the product may be accepted. Just what quality it pays him to submit depends, of course, on his circumstances. There are many chance variations of quality and these would probably be normally distributed around the AQL. Besides chance variations in quality, however, there are variations produced by "assignable causes." For the most part, assignable cause consist of:

A. Differences among machines

B. Differences among workers

C. Differences among materials

D. Differences in each of these factors over time

E. Differences in their relationships to one another

These "assignable causes" are within the power of the vendor to control to a certain extent. In trying to exactly produce material to the AQL standard, the vendor realizes some will be above and some will be below. Each variation from the AQL has some binomial probability associated with it that the lot will either be accepted or rejected. The control of these "assignable causes" can be translated into cost to the vendor. The vendor knows that for each degree of control there is an associated probability of lot rejection which he learns by experience. The vendor must view this

experience in terms of the presentation of many lots for inspection over a period of time. This fact, and the fact that his control over the "assignable causes" to reduce his probability of rejection, results in a distribution of rejection rates skewed drastically to the right having much similarity to a Beta distribution. The mathematical accuracy of this statement is proven in Appendix 1. For the purposes of this discussion we will assume that the vendor can afford to have one lot in ten (10%) rejected but he wants a very low probability of greater than 10% rejection rate. Figure 1 is the graph of such a probability distribution. It has an expected value of .1 and a mode (most frequent) of .0555. (See Appendix 2). Since the area under the curve represents the vendors rejection rate, it is obvious that most of the area is between 0 and .2. This means that the vendor will have a very low probability of having more than 2 out of ten lots rejected.

This distribution and the associated statistics will be important in a derivation of the expected rejection rate for the origin inspection process.

IV. ORIGIN INSPECTION

Military Standard 105D "Sampling Procedures and Tables for Inspection by Attributes" outlines the acceptance sampling plan for most subsistence items. This document is normally referenced in the contract with the vendor.

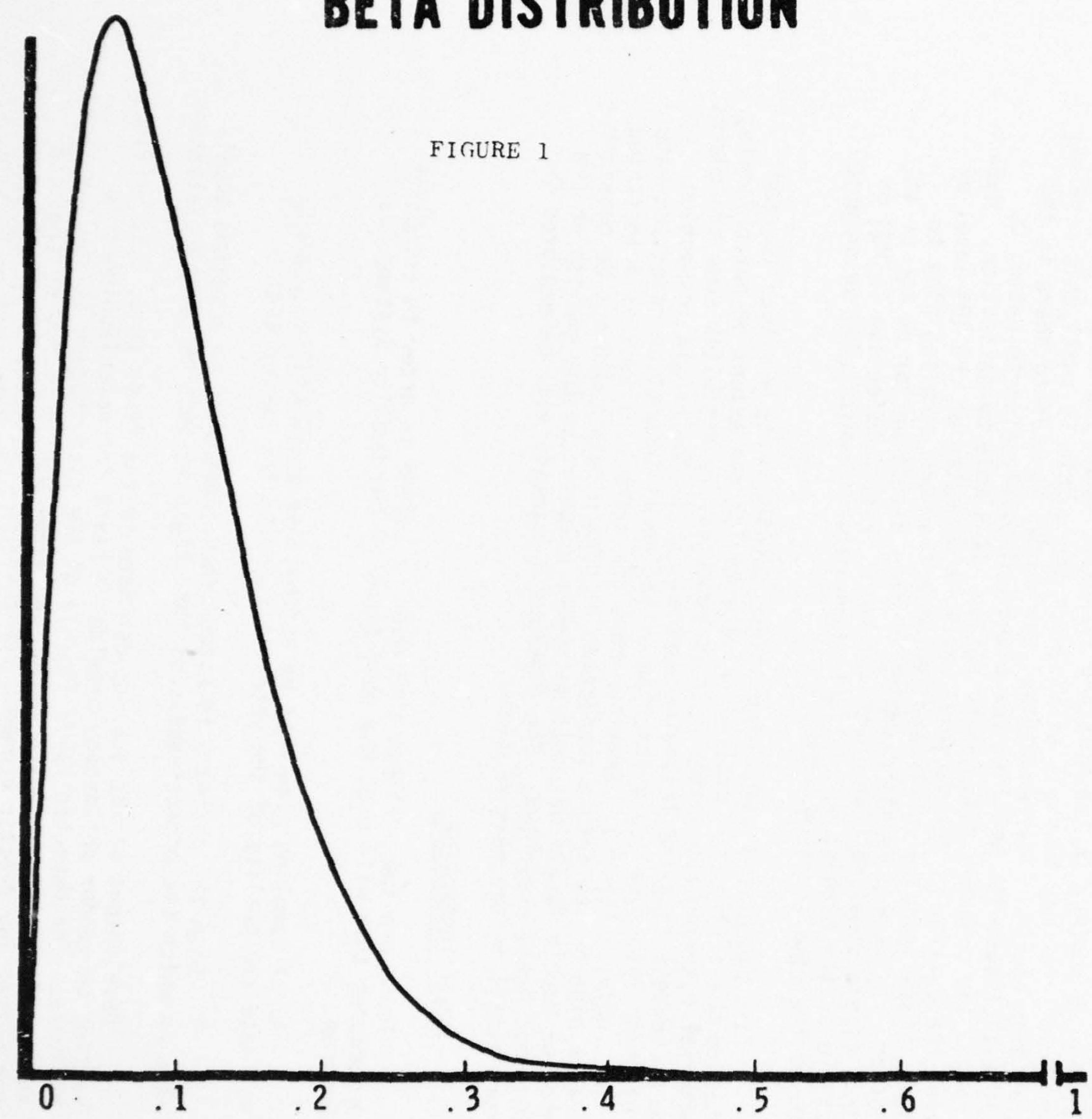
It should be pointed out that the purpose of acceptance sampling is to determine a course of action (i.e., accept or reject), not to estimate lot quality. Acceptance sampling prescribes a procedure that, if applied to a series of lots, will give a specified risk of accepting lots of given quality. If the lots are all of the same quality, acceptance sampling will accept some and reject others, and the accepted lots will be no better than the rejected lots. If lots differ in quality, the sampling plan will accept the good lots more frequently than it will the bad lots and in this way "average up" the quality of accepted material.

Acceptance sampling is used when the cost of inspection is high and the loss arising from passing a defective lot is not high and/or when the inspection is destructive.

Military Standard 105D outlines such an acceptance sampling plan. The AQL is the driving factor of this plan. There are advantages and disadvantages to this approach. Under this plan all vendors of the same product have the same AQL. If the AQL is the same for different vendors of the same product, they are all likely to operate at much the same quality level, since the AQL defines a quality at which rejections are low (5%) and since suppliers of the same product are likely to be industrially similar. This premise supports the assumptions of the previous section. The pressures on the suppliers depend to some extent on the amount of inspection per inspection lot. If the amount of inspection per inspection lot is small, the vendor will find that a slight decrease in the quality of product submitted will increase rejections only moderately; whereas, if the amount of inspection per inspection lot is large, the same decrease in

BETA DISTRIBUTION

FIGURE 1



quality will increase rejections sharply. This is a result of poorly discriminating OC curves resulting from small sample sizes. In connection with the discussion of AQL, it is important to point out the fallacy of a popular misconception concerning these OC curves. The vendor risks and consumer risk associated with the MIL-STD 105D sampling plans are commonly believed to be 5% and 10% respectively. That is the plans will reject good lots 5% of the time and accept bad lots 10% of the time. This statement is not completely accurate. The vendor risk varies considerably from one plan to another in the Military Standard. When the sample is large, the vendor risk may be small as 1%; when the sample is small, this risk may be as high as 20%. This means that the vendor is made to share in the risk associated with small sample sizes and poorly discriminating OC curves. The consumer risk can be set at 10% simply by definition. However, the quality of the material which is accepted at the 10% level by the Military Standard varies considerably from one sampling plan to another. Table 4 presents examples of this situation for an AQL of 4% for a single sampling plan. Lot Tolerance Percent Defective (LTPD) is defined as the highest percent defective material which will be accepted 10% of the time (consumer risk).

This background concerning origin inspection is provided to reemphasize the difficulty involved in determining the extent of nonconforming material entering the system. It is necessary to establish some procedures to accurately test the following hypothesis: Is the origin inspection rejection rate equal to a function of the audit inspection rejection rate (i.e., $Ho: p_1 = F(p_1)$). Remember that the example of Section 3 indicated that a high or low origin inspection rejection rate could not be considered good or bad in itself but must be viewed relative to the quality of the material being presented. The previous hypothesis will be explored in more detail in the next section.

V. AUDIT INSPECTION

There are two problems that must be solved in order to establish procedures that will meet the objectives of the Quality Systems Audit Program.

A. A sampling plan must be established which will accurately estimate the quality of the material entering the system and:

B. Once the estimate is established, there must be a method available by which the effectiveness of the origin inspection can be evaluated.

Development of the quality estimate is the first task. The previous section on vendor philosophy provides a basis for establishing this estimate. The expected value (E (x)) of the distribution is the "average" number of rejections that a vendor can allow over a period of time and not suffer any drastic economic consequences. If the origin inspection is perfect, a certain portion of these rejectable lots will be passed and a portion of the acceptable lots will be rejected. These risks are normally referred to as consumer and vendor risks respectively as stated

TABLE 4

AQL = 4% CONSUMER RISK = 10%

SAMPLE SIZE	VENDOR RISK	LTPD
3	11.5%	53.6%
13	9.3%	26.8%
20	4.4%	24.5%
32	3.8%	19.7%
50	1.5%	17.8%
80	1.5%	14.2%
125	1.2%	12.3%

earlier. While the Military Standard allows variance in these risks with respect to sample size, for our purposes we will assume that these risks are constant on the average and have the following values:

A. Consumer risk $\beta = 10\%$

B. Vendor risk $\alpha = 5\%$

If these assumptions are fairly accurate, it is possible to derive a formula for the expected origin rejection rate which is a function of the vendors philosophy concerning rejections. If X represents a rejectable lot then;

$$E(ORR) = .05 + .85\,(E\,(x)) \qquad (1)$$

The details of this derivation can be found in Appendix 3. The origin rejection rate can be directly observed and calculated by the following formula:

$$ORR = \frac{\#\text{Rejections at Origin}}{\text{Total Inspections at Origin}} \qquad (2)$$

This equation (2) combined with (1) will provide a relationship which can be tested in a sampling plan.

$$E\,(x) = \frac{ORR - .05}{.85} \qquad (3)$$

The audit inspection will provide a sample designed to establish an estimate of E (x) for testing the hypothesis of (3). Testing of this hypothesis could provide the following conclusions:

A. $E\,(x) > \frac{ORR - .05}{.85}$. This would imply that the origin inspection was not effectively controlling quality in the intended manner.

B. $E\,(x) < \frac{ORR - .05}{.85}$. This would imply that the origin was too rigid, rejecting too many lots that should be accepted.

C. $E\,(x) = \frac{ORR - .05}{.85}$. This case would rarely ever happen but would imply that inspection was perfect.

D. $E\,(x) \simeq \frac{ORR - .05}{.85}$. This case would arise as a result of the sampling tolerances which must be incorporated in the plan to keep sample sizes manageable. We will only have accuracy to plus or minus some predetermined percentage which will provide a range for comparison.

Case D will become clearer from the subsequent discussion of sampling plans.

VI. SAMPLING PLAN FOR AUDIT INSPECTION

There are many statistical tests available for the purpose of testing for differences between two proportions. The method chosen in this section is a form of sequential analysis. The reason for choosing this method was to attain a degree of accuracy high enough to generate confidence in the decision while maintaining sample sizes at the lowest possible level.

Throughout this section there will be no reference made to consumer or vendor risk. Instead the more commonly accepted α and β risks will be used. These are directly analagous to vendor and consumer risks. The α and β risks are directly related to hypothesis testing and are defined as follows:

α = probability of rejecting a hypothesis when it is true.

β = probability of accepting a hypothesis when it is false.

Recall equation (3) of section V.

$$E\ (x) = \frac{ORR - .05}{.85}$$

where ORR = Origin inspection rejection rate. Realizing that a portion of the rejectable lots are passed as a result of the consumer risk (10%) we can modify this equation so that E (x) = the expected amount of nonconforming lots entering the system. The audit inspection rejection rate should closely approximate E (x). Thus,

$$E\ (x) = \frac{(.1)\ ORR - .005}{.85} \qquad (1)$$

Equation (1) will be the hypothesis we intend to test. If in testing a hypothesis we wish to decide in advance what risks we are willing to take of rejecting a true hypothesis α or of accepting a false hypothesis β, our sample size is determined. This assumes, however, that we are going to take a sample of this size no matter what results we obtain from our first few observations. In practice it is not necessary to request a procedure which would require more observations than are necessary to make a decision. Sequential analysis is a procedure which leads to a statistical inference and in which the number of observations to be made is not determined before the experiment is begun. The procedure indicates when sufficient observations have been gathered to make our decisions with the risks we have chosen. On the average, fewer observations will be required by this procedure, and its use will not increase the α and β risks. For some cases only half the number of observations will be required on the average for the sequential procedure as compared with the number required if the sample size is fixed in advance.

This procedure of testing a hypothesis can be characterized as

follows: Observations are taken one at a time. After every observation we decide to do one of the following three things:

A. Accept the hypothesis

B. Reject the hypothesis

C. Make an additional observation

Suppose we wish to reject the hypothesis (1) only 5% of the time if the audit rejection rate is $\frac{(.1)\ ORR - .005}{.85}$.

This means that we will determine that the origin inspection process is not effective when it really is effective. This could occur 5% of the time. Also, suppose we will accept the hypothesis 20% of the time if the audit rejection rate is $\frac{(.1)\ ORR - .005}{.85} + K$.

K is a constant percentage error which will be defined in the test. This means that we will accept the conclusion that the origin inspection process is effective when it actually is not. This will occur 20% of the time. These stated risks will lead to the following hypothesis:

$$H_0:\ E(x) = \frac{(.1)\ ORR - .005}{.85} = P_0$$

$$H_1:\ E(x) = \frac{(.1)\ ORR - .005}{.85} + K = P_1$$

$$\alpha = 5\%$$

$$\beta = 20\%$$

K = Constant Factor.

Suppose we select lots at random. If we assume that P_1 is the proportion of bad lots in the system, then the probability that the audit inspection would discover d_L defective lots and g_L good lots in some order among the first m observations is:

$$P_{1m} = P_1^{d_L} (1-P_1)^{g_L} \qquad (2)$$

where $(d_L + g_L = m)$.

Similarly, if the proportion of bad lots is P_0, then:

$$P_{0m} = P_0^{d_L} (1 - P_0)^{g_L} \qquad (3)$$

The ratio

$$\frac{P_{1m}}{P_{om}} = \frac{(P_1)}{(P_o)}^{d_L} \frac{(1-P_1)}{(1-P_o)}^{g_L} \qquad (4)$$

can be transformed to natural logarithms.

$$\ln \frac{P_{1m}}{P_{om}} = d_L \ln \frac{P_1}{P_o} + g_L \ln \frac{1-P_1}{1-P_o} \qquad (5)$$

It can be shown mathematically that the critical values may be obtained by setting:

$$d_L \ln \frac{P_1}{P_o} + g_L \ln \frac{1-P_1}{1-P_o} = \ln \frac{1-\beta}{\alpha}. \qquad (6)$$

and

$$d_L \ln \frac{P_1}{P_o} + g_L \ln \frac{1-P_1}{1-P_o} = \ln \frac{\beta}{1-\alpha}. \qquad (7)$$

While the previous explanation may appear complicated, it can be simply demonstrated by use of an example.

Suppose the origin rejection rate (ORR) was observed at 13.5%. Then substitution into 1 yields E (x) = 1% (.01). This 1% figure follows from the section on the discussion of vendor philosophy. (It is important to point out that the accuracy of this hypothesis test is not dependent on any assumptions of that section.) This then would provide the following hypothesis for testing.

H_o: E (x) = .01 (P_o)

H_1: E (x) = .025 (P_1)

α = 5%

β = 20%

K = 1.5% (.015)

The constant factor was chosen arbitrarily but is within reasonable limits for this type of test.

Substituting these values into equations (6) and (7) gives:

$$d_L \ln \frac{.025}{.01} + g_L \ln \frac{.975}{.99} = \ln \frac{1-.2}{.05}$$

and

$$d_L \ln \frac{.025}{.01} + g_L \ln \frac{.975}{.99} = \ln \frac{.2}{1-.95} .$$

Substituting values of logarithms we obtain:

$$.9163 d_L - .01527 g_L = 2.773$$

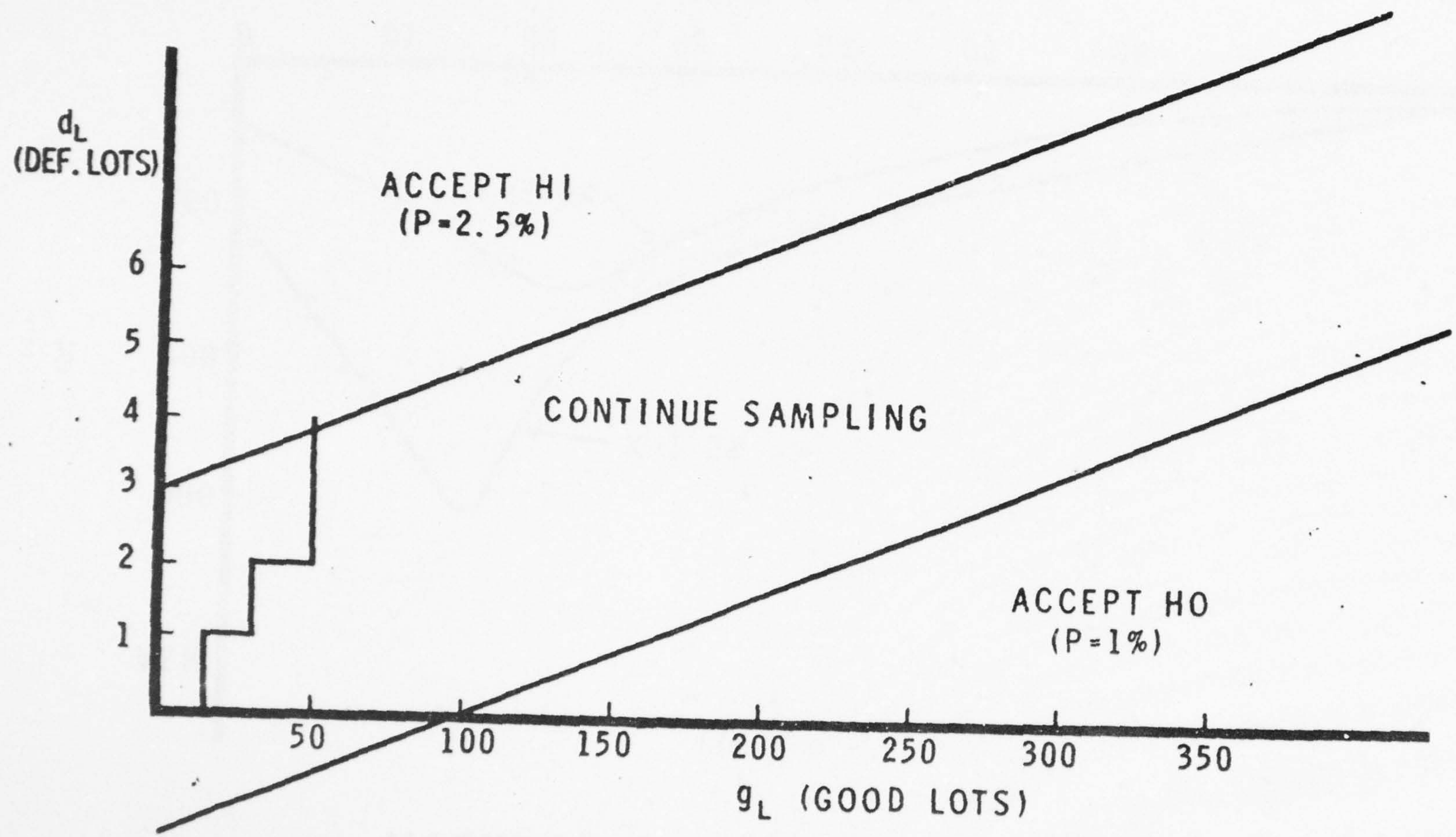
$$.9163 d_L - .01527 g_L = 1.558 .$$

These equations can be represented by lines on a graph. The resultant graph is shown on Figure 2.

The use of the graph provides a unique advantage to the audit inspection process. In many cases the individuals monitoring the program may not be statistically or mathematically oriented. Prior construction of the graphs by qualified personnel will enable the monitors to simply graph each good and bad lot. The decision occurs anytime the graphed line crosses either of the boundary limits.

The actual sample size required to make a decision will vary with the true quality of the material in the system. From Figure 2 it is apparent that if 4 lots are rejected in 60 or less total audits, then the hypothesis (H_1) that p=.025 would be accepted indicating that the origin inspection process was not effective. If no lots were rejected during audit, it would require inspection of 102 lots to accept (H_0) p=.01 indicating that the origin inspection process was effective. The average sample size required to make a decision is a function of the quality of the material and the degree of accuracy desired. Figure 3 is a graph of the average sample number for the previous example and also presents the effect of increasing the constant factor (k) to 3%. Details covering construction of this curve are contained in Appendix 4. The Operating Characteristic curves are approximated for each of these cases and included as Figure 4. The mathematical considerations used in construction of these curves are contained in Appendix 5. Review of Figure 4 demonstrates the problem encountered in attempting to decrease sample size by allowing more variance in the estimate. The perfect curve for this test would be the Z shaped curve shown in red. This could only be achieved, however, with 100% inspection. The closer we approximate this Z shaped curve, however, the more confident we can be in our decision. As the curve gets flatter as a result of a decrease in sample size, we have less confidence.

FIGURE 2



d_L
(DEF. LOTS)
ACCEPT HI
(P=2.5%)
CONTINUE SAMPLING
ACCEPT HO
(P=1%)
6
5
4
3
2
1
50
100
150
200
250
300
350
g_L (GOOD LOTS)

AVERAGE SAMPLE NUMBER (ASN)

FIGURE 3

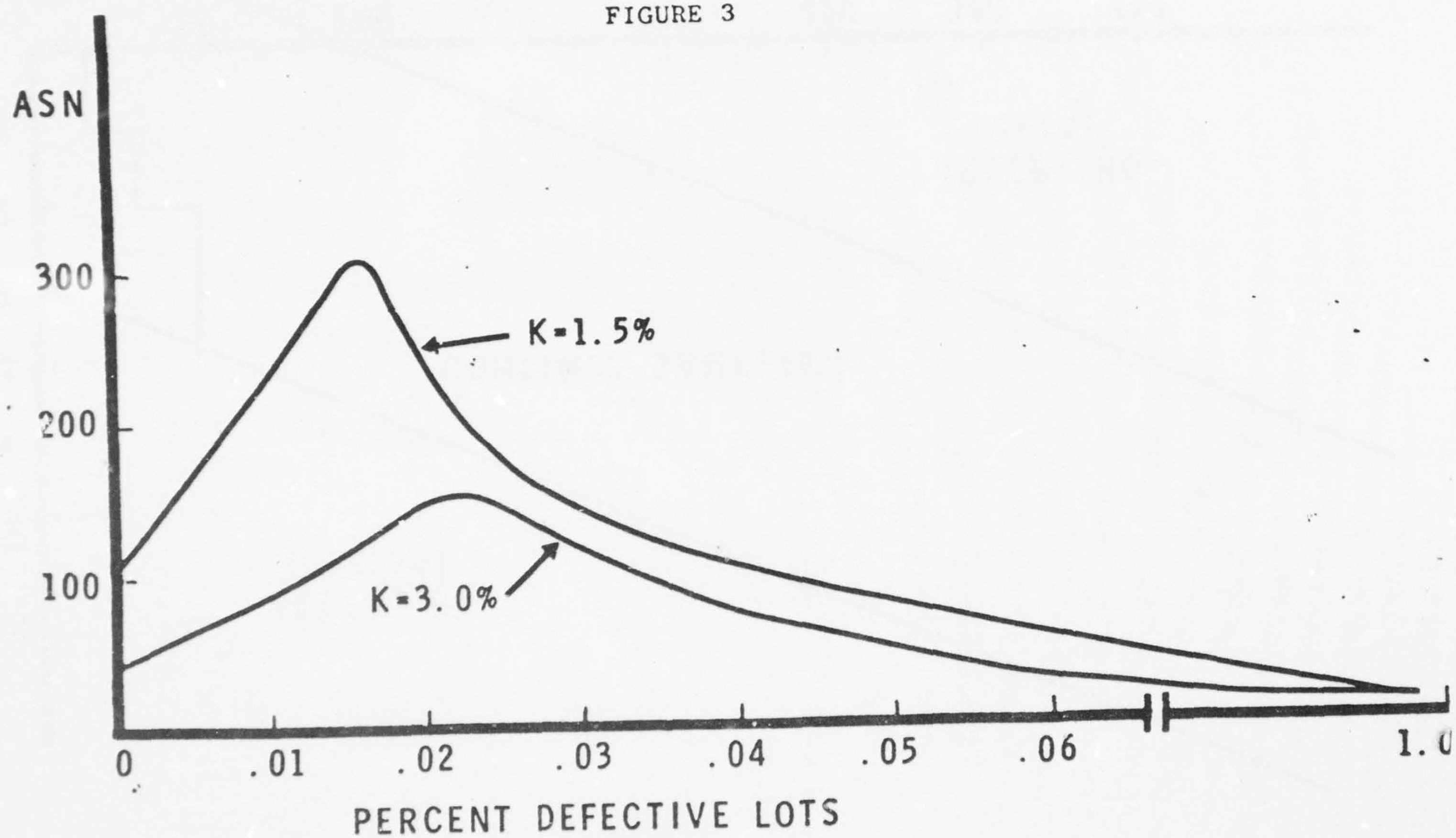


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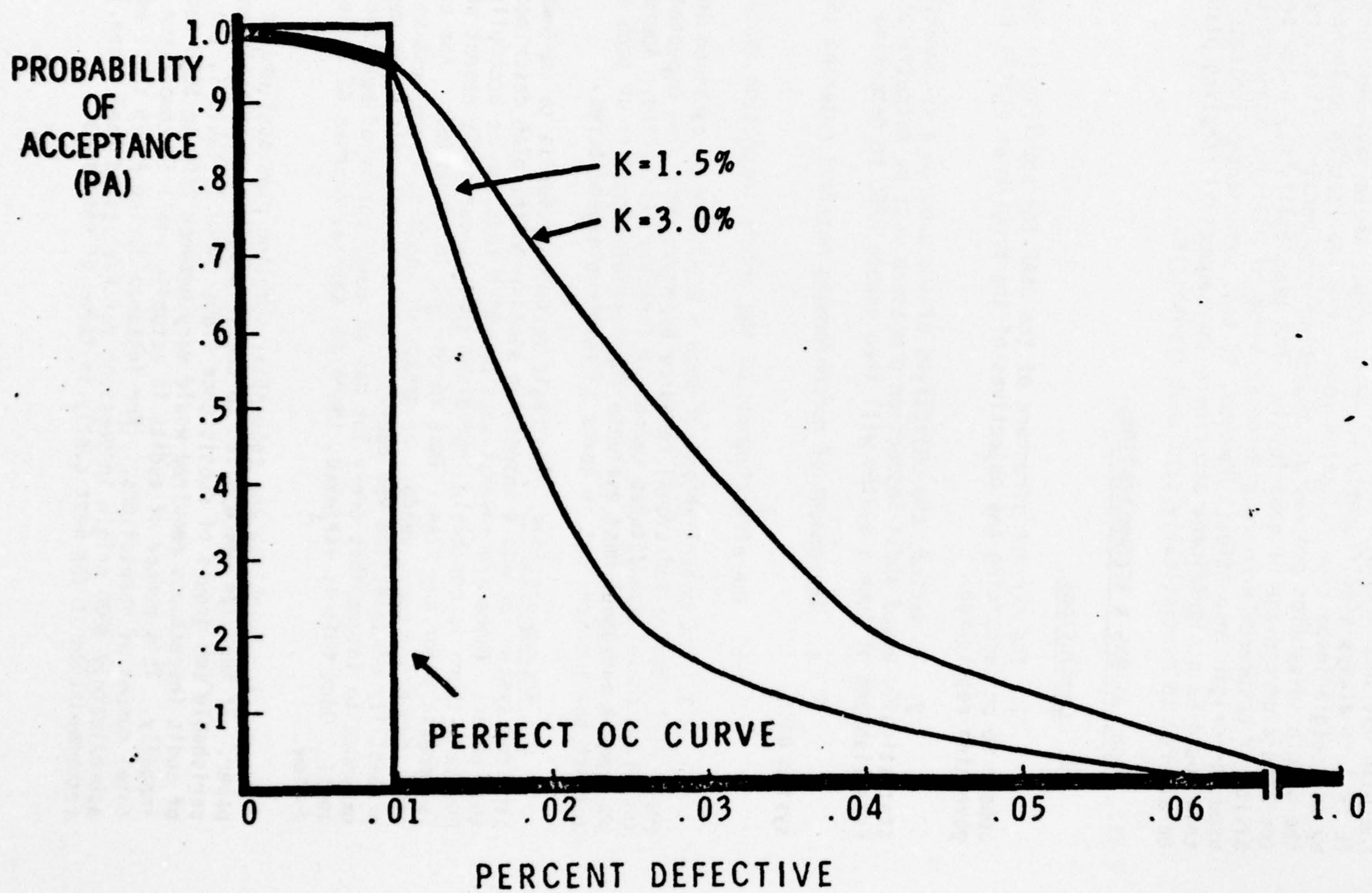
FIGURE 4

OPERATING CHARACTERISTIC CURVES



There is one possible testing result which we have not covered by the plan outlined above. This is the case where the audit rejection rate (E (x)) is always significantly lower than what would have been predicted by the origin inspection rejection rate. The implication could be that the origin inspection process was rejecting lots unfairly (i.e., rejecting too high a percentage of good lots). This possibility has a low probability of occurance when considered in terms of Military Standard 105D used for origin inspection. However, if test experiences indicate that this could be a significant occurrence the sequential sampling plan could be altered to statistically test that hypothesis.

VII. CONCLUSIONS & RECOMMENDATIONS

A. Conclusions

1. The current structure of the QSAP for subsistence does not appear to be satisfying the objectives of the program as stated in the governing regulation.

2. To satisfy the objectives of the program a systematic, statistically based audit inspection procedure must be established. Establishment of such a system will then enable DPSC to determine:

a. The amount of nonconforming material entering the system and;

b. The effectiveness of the origin inspection system.

3. The establishment of such a procedure as outlined in this paper will require additional resource expenditures. The expected return from these expenditures cannot be directly quantified. Appropriate management personnel must evaluate the possible benefits of such a system against the implied cost in terms of resource expenditures.

B. Recommendations. The basic recommendation is to implement a sampling system for audit inspection similar to the plan described in this paper. There are several ways by which this can be accomplished. However, there is one basic ingredient that is currently absent which is necessary for any plan. That ingredient is randomness. For each item, group of items, vendor, or groups of vendors, there must be an equal probability of selection for audit. The number of audit sites must be expanded to insure that every lot has an equal chance of selection for audit. Once this is achieved, there are several courses of action to follow.

1. Establish the sequential sampling plan outlined in this paper. If the plan was applied to the 17 groups of perishable and non-perishable sub groups of subsistence items shown in Table 1, the number of audit inspections required would vary between 2500 to 5000 audits annually. This number of audits is actually small in comparison to the total number of inspections. (For instance during FY 75 there were approximately 8000 origin inspections for Fabricated Beef alone.) This recommendation is the most costly in terms of resources.

2. Establish the same system as defined above but over a longer time frame. If it is decided that it is not imperative to develop an annual estimate, the number of required samples could be distributed over a larger time frame. For example, 2 or 3 years. This recommendation would be less costly than 1.

3. Lastly, we could continue to operate the system as it currently exists but to aggregate the current data in the form described in this paper. This is basically the same as recommendation 2 with no time frame specified. It is not possible to determine how long or if we would ever have an accurate estimate to use,but this would be the least costly route to take.

C. Additional Recommendation. The theory associated with sequential analysis is well documented and substantiated in statistics. The same approach could be effectively and economically applied to the origin inspection process. Currently, the origin inspector selects his sample of a predetermined size and then counts the defective and good material and makes a determination concerning acceptability of the lot. Using sequential sampling, it would often be possible for the origin inspector to make his determination in less than the predetermined sample size. This would effect economies in the inspection process and would also prove beneficial to the vendor. If a lot was going to be rejected, the vendor would like to know as soon as possible so that the production line could be shut down and suitable adjustments made. Application of this plan can be easily simplified to require no statistical knowledge on the part of the inspector.

APPENDIX 1

PROOF THAT A SUM OF BINOMIAL PROBABILITIES IS EQUAL TO A BETA DISTRIBUTION

Consider the Cumulative Distribution Functions

$$\sum_{c=0}^{N} \binom{N}{c} p^c q^{N-c} = \frac{(a + b + 1)!}{a!\, b!} \int_0^x x^a (1 - x)^b \, dx$$

where $q = (1 - p)$

Let $x = q$ and expand the left side

$$q^N + Nq^{N-1} p + \cdots + \frac{N(N-1) \cdots (N-c+1)}{c!} q^{N-c} p^c = \frac{(a+b+1)!}{a!\, b!} \int_0^q q^a (1-q)^b \, dq$$

Differentiate both sides WRT q

$$Nq^{N-1} + N(N-1)q^{N-2} p + \cdots + \frac{N(N-1) \cdots (N-c+1)}{(c-1)!} q^{N-c} p^{c-1}$$

$$+ \frac{N(N-1) \cdots (N-c)}{c!} q^{N-c-1} p^c - Nq^{N-1} - \frac{N(N-1)}{2} q^{N-2} (2p) - \cdots$$

$$- \frac{N(N-1) \cdots (N-c-1)}{c!} q^{N-c} (cp^{c-1}) = \frac{(a+b+1)!}{a!\, b!} q^a (1-q)^b$$

Cancellation of terms on the left yields

$$\frac{N(N-1) \cdots (N-c)}{c!} q^{N-c-1} p^c = \frac{(a+b+1)!}{a!\, b!} q^a (1-q)^b$$

Since $q = x$ implies $p = 1-x$

$$\text{Let} \quad \left.\begin{aligned} a &= n-c-1 \\ b &= c \end{aligned}\right\} \text{ implies } n = a+b+1$$

$$\text{Thus} \quad \frac{(a+b+1)\,(a+b+1-1) \cdots (a+b+1-b)}{b!} x^{N-c-1} (1-x)^b = \frac{(a+b+1)!}{a!\, b!} x^a (1-x)^b$$

Multiply the left by $\frac{a!}{a!}$ and

$$\frac{(a+b+1)!}{a!\, b!} x^a (1-x)^b = \frac{(a+b+1)!}{a!\, b!} x^a (1-x)^b.$$

APPENDIX 2

BETA DISTRIBUTION

The values used to derive Figure 1 were developed from the Beta Probability Density Function

$$F(x) = \frac{(a + b + 1)!}{a!\ b!}\ x^a\ (1 - x)^b \quad , \quad \text{for } 0 < x < 1$$

$$= 0 \text{ , elsewhere.}$$

With parameters a = 1, b = 17 this yields

$$E(x) = \frac{a + 1}{a + b + 2} = .1$$

$$\sigma^2 = \frac{(a + b + 2)\ (a^2 + 3a + 2) - (a + 1)^2\ (a + b + 3)}{(a + b + 2)^2\ (a + b + 3)} = .00204$$

$$\text{Mode} = \frac{a}{a + b} = .0556$$

The probabilities defined as the area under the curve can be computed from the cumulative distribution function.

$$F(x) = 0 \qquad\qquad x < 0$$

$$= \int_0^x \frac{(a + b + 1)!}{a!\ b!}\ x^a\ (1 - x)^b\ dx \qquad 0 < x < 1$$

$$= 1 \qquad\qquad x > 1$$

For the example a = 1, b = 17 the following probabilities were approximated using Simpson's approximation

P (x .0556) = .28

P (x .075) = .42

P (x .1) = .58

P (x .2) = .91

P (x .3) = .98

P (x .4) = .999

APPENDIX 3

DERIVATION OF EXPECTED REJECTION RATE

The Pdf of the Beta Distribution is

$$F(x) = \frac{(a + b + 1)!}{a!\, b!} x^a (1 - x)^b, \quad 0 < x < 1$$

$$= 0, \text{ elsewhere}.$$

Let x = percent of lots submitted which are rejectable since we assume $\alpha = .05$ and $\beta = .1$.

Then (assuming perfect inspection) the percent of rejected lots will be

$$R = (.9\, x + .05\, (1 - x)).$$

Then

$$E(R) = \frac{(a + b + 1)!}{a!\, b!} \int_0^1 (.9X + .05\, (1 - x))\, x^a (1 - x)^b\, dx$$

$$= \frac{(a + b + 1)!}{a!\, b!}\, .05 \int_0^1 x^a (1 - x)^b\, dx +$$

$$.85\, \frac{(a + b + 1)!}{a!\, b!} \int_0^1 x^{a+1} (1 - x)^b\, dx$$

$$= .05 + .85\, E(x).$$

APPENDIX 4

AVERAGE SAMPLE NUMBER

Calculation of points on the average sample number curve is a rather complicated mathematical exercise involving application of the maximum likelihood ratio. There are several points, however, which can be determined easily and used to sketch the approximate shape of the curve as shown in Figure 3.

Let P_0 = desired quality at α

P_1 = lot tolerance percent defective

1. If all items obtained are defective:

$$\frac{\ln \frac{1-\beta}{\alpha}}{\ln \frac{P_1}{P_0}} = N$$

2. If all items obtained are good:

$$\frac{\ln \frac{\beta}{1-\alpha}}{\ln \frac{1-P_1}{1-P_0}} = N$$

3. At P_0:

$$\frac{(1-\alpha) \ln \frac{\beta}{1-\alpha} + \alpha \ln \frac{1-\beta}{\alpha}}{P_0 \ln \frac{P_1}{P_0} + (1-P_0) \ln \frac{1-P_1}{1-P_0}} = N$$

4. At P_1:

$$\frac{\beta \ln \frac{\beta}{1-\alpha} + (1-\beta) \ln \frac{1-\beta}{\alpha}}{P_1 \ln \frac{P_1}{P_0} + (1-P_1) \ln \frac{1-P_1}{1-P_0}} = N$$

5. At P' where $P_0 < P' < P_1$

$$P' = \frac{\ln \frac{1-P_1}{1-P_0}}{\ln \frac{1-P_1}{1-P_0} - \ln \frac{P_1}{P_0}} \qquad N = \frac{\ln \frac{\beta}{1-\alpha} \ln \frac{1-\beta}{\alpha}}{\ln \frac{P_1}{P_0} \ln \frac{1-P_1}{1-P_0}}$$

APPENDIX 5

OPERATING CHARACTERISTIC CURVE

Calculation of all points on the OC curves for a sequential sampling plan is complicated by the necessity to solve two parametric equations. It is possible to readily determine five points from which the curve can be sketched.

	OC FUNCTION
1. At $P = 0$	1
2. At $P = P_0$	$1 - \alpha$
3. At $P = P_1$	β
4. At $P = 1$	0
5. At $P = P'$	$\dfrac{\ln \frac{1-\beta}{\alpha}}{\ln \frac{1-\beta}{\alpha} \ \ln \frac{\beta}{1-\alpha}}$

where

$$P' = \frac{\ln \dfrac{1-P_1}{1-P_0}}{\ln \dfrac{1-P_1}{1-P_0} - \ln \dfrac{P_1}{P_0}}$$

THE BID EVALUATION MODEL

by Major James Bexfield

CHART 1

First I will describe the problem - followed by an example that will be used later to help explain some of the theory in the model. This will be followed by the development of the theory used in the bid evaluation model.

CHART 3

How does DoD purchase fuel? First, we obtain requirements from the Military Services. After evaluating these requirements, we request bids from industries. These bids are evaluated using the bid evaluation model.

What does a typical bid look like? It specifies an amount which is an upper limit, that is we can accept less than that amount but not more. Likewise a price is specified. The bid is either an origin bid, in which case we supply the transportation, or a destination bid, in which case the company supplies the transportation.

There are several complications in the evaluation of these bids. First, with respect to origin bids, we need transportation rates between the origins and the destinations. Second, companies may submit several bids and indicate a maximum total offer. For example, a company might make three destination bids to destinations A, B, and C, each one for one million gallons, and specify that their maximum total offer is 1.5 million gallons. Third, companies frequently do not want to deal with the Government for small quantities so they will specify minimum acceptable quantities. In other words, the Government must accept this minimum quantity or nothing at all. Finally, occasionally companies will tie their bids together. This could occur if two companies are bidding based on using the same refinery. In a tie-in bid the amount that can be accepted from one company is reduced by the amount accepted by the other company.

As you can see, the problem of selecting those bids that result in the lowest delivered fuel cost is a complex one.

CHART 5

In this example we have 3 oil companies (C1, C2, C3) making bids to satisfy requirements at 2 <u>bases</u> - B1 with a requirement of 500 and B2 with a requirement of 600. There is a single transhipment point labeled D. Note the many different ways fuel can be transported.

OUTLINE

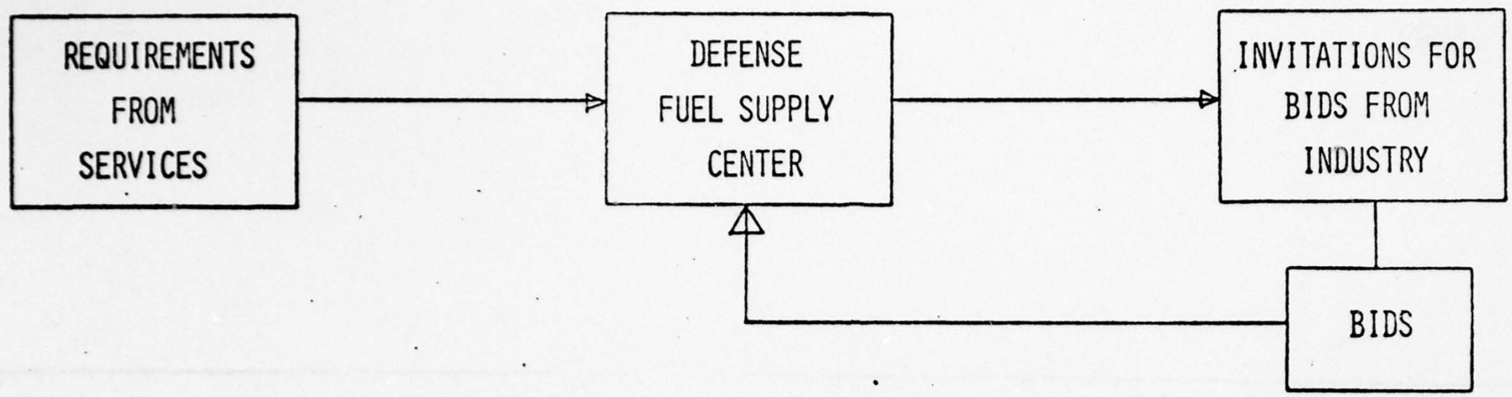
- o THE PROBLEM
- o AN EXAMPLE
- o THE BID EVALUATION MODEL
- o MODEL USAGE

CHART 1

THE PROBLEM

CHART 2

HOW DOES DOD PURCHASE FUEL



- A BID:

	AMOUNT	PRICE	LOCATION
	100,000	.3142	ORIGIN OR DESTINATION

- COMPLICATIONS
  - TRANSPORTATION COSTS
  - MAXIMUM TOTAL OFFER
  - MINIMUM ACCEPTABLE QUANTITIES (MAQ)
  - TIE-IN-BIDS
- PROBLEM: SELECT THOSE BIDS THAT RESULT IN LOWEST DELIVERED FUEL COST

CHART 3

AN EXAMPLE

CHART 4

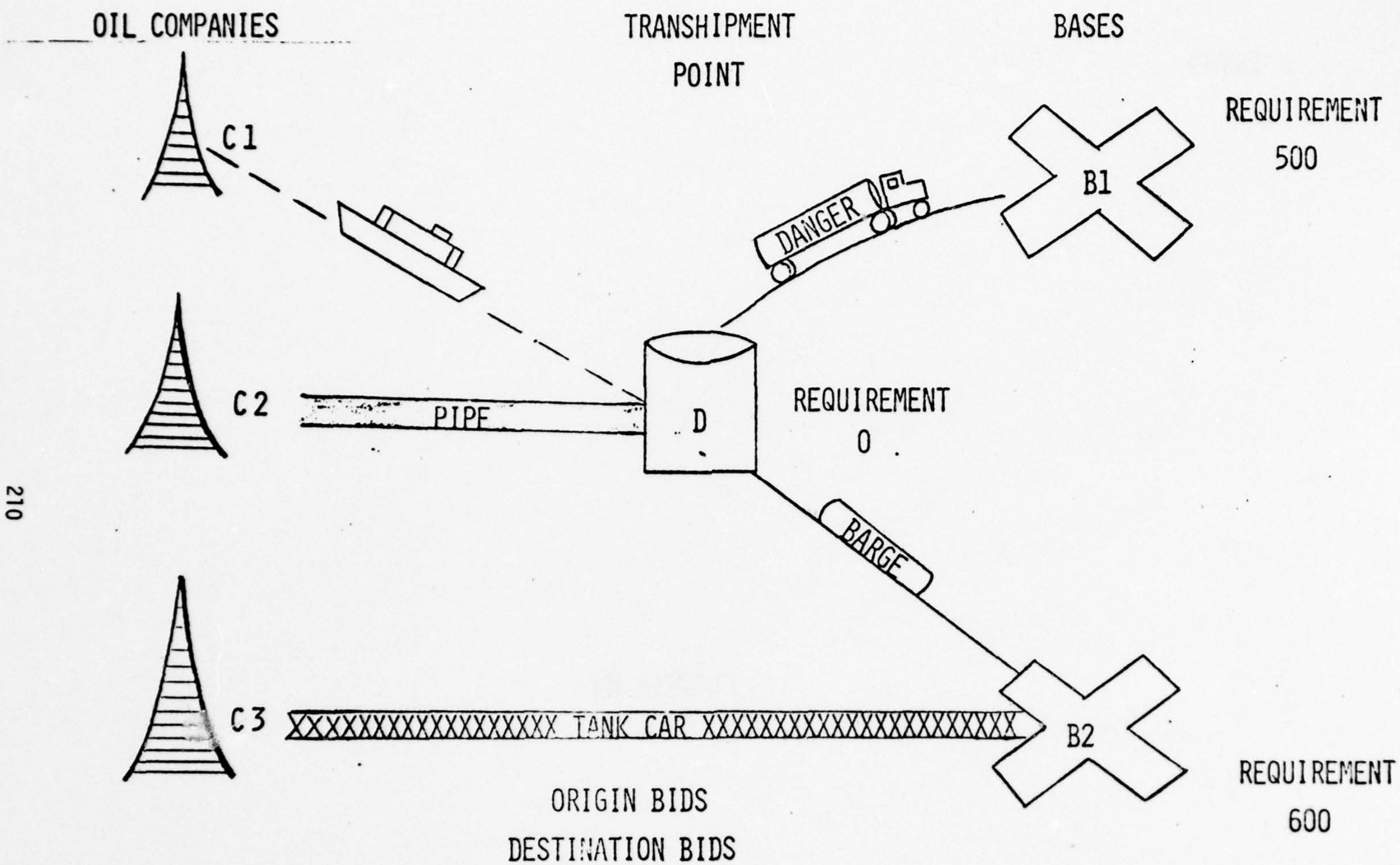

OIL COMPANIES
TRANSHIPMENT
POINT
BASES
REQUIREMENT
500
C1
DANGER
B1
C2
PIPE
D
REQUIREMENT
0
BARGE
C3
TANK CAR
B2
ORIGIN BIDS
DESTINATION BIDS
REQUIREMENT
600

CHART 5

CHART 6

This chart contains the bids and restrictions for the example problem. The first bid is from company 1 for 1,000 units. It is an origin bid with the location designated by S1 and it costs $800 per unit. The second and third bids are destination bids from company 1, each with amounts of 300 units. Note that the total amount company 1 has bid is 1,600 units, but they have a company limit of 1,000. In addition, company 1 restricts the amount of bid 2 plus bid 3 to be less than or equal to 500, even though the total amount for these two bids is 600 units. There are similar bids and restrictions for companies 2 and 3. All bids have a minimum acceptable quantity of 200. In other words, for each bid we must accept at least 200 or nothing at all. Finally, there is a tie-in bid between company 1 and company 2.

CHART 7

Since we are interested in minimizing the delivered fuel costs, we must consider transportation rates for shipments from the transhipment point D and from the location of the origin bid (S1) to the possible destinations. In this example it costs $400 per unit to ship our product from the transhipment point D to the destination B1 by truck.

CHART 8

It is now time to describe the BEM model. This description is divided into 2 parts - first a network representing all the constraints - max flow, min flows, etc. is built. Then a mathematical model is developed to represent this network.

CHART 9

A network consists of flows along arcs to nodes. The flows along the arcs are constrained by capacity limits. One constraint specifies that a certain amount must flow into the sink. Associated with each arc is a cost/unit of flow. The objective is to determine the flow along each arc so as to minimize the total cost of the flow through the network while satisfying all constraints.

CHART 10

In our case an arc will be represented by a three-tuple. The first position represents the maximum amount, for example the bid amount or maximum sale for a given company; the second position represents the minimum amount, for example a requirement or MAQ; the third position represents the cost associated with flows over that arc. Next we will learn how to represent the various bids and constraints using a network.

BIDS

#	COMPANY	AMOUNT	DESTINATION	COST/UNIT
1	C1	1,000	ORIGIN (S1)	$ 800
2	C1	300	B1	$ 850
3	C1	300	D	$ 900
4	C2	500	D	$ 800
5	C2	500	B2	$ 1,200
6	C3	600	B2	$ 1,000

RESTRICTIONS

- o COMPANY LIMITS C1: MAXIMUM OF 1,000
  C2: MAXIMUM OF 500
- o MAXIMUM AMOUNT: AMOUNT OF BID 2 + BID 3 LESS THAN OR EQUAL TO 500
- o MINIMUM ACCEPTABLE QUANTITIES (MAQ): 200 FOR ALL BIDS
- o TIE-IN-BIDS: AMOUNT OFFERED BY C1 IS REDUCED BY AMOUNT AWARDED C2

CHART 6

TRANSPORTATION COSTS

SOURCE	DESTINATION	METHOD	COST/UNIT
D	B1	TRUCK	$ 400
D	B2	BARGE	$ 100
S1	B1	TANK CAR	$ 100
S1	D	TRUCK	$ 200

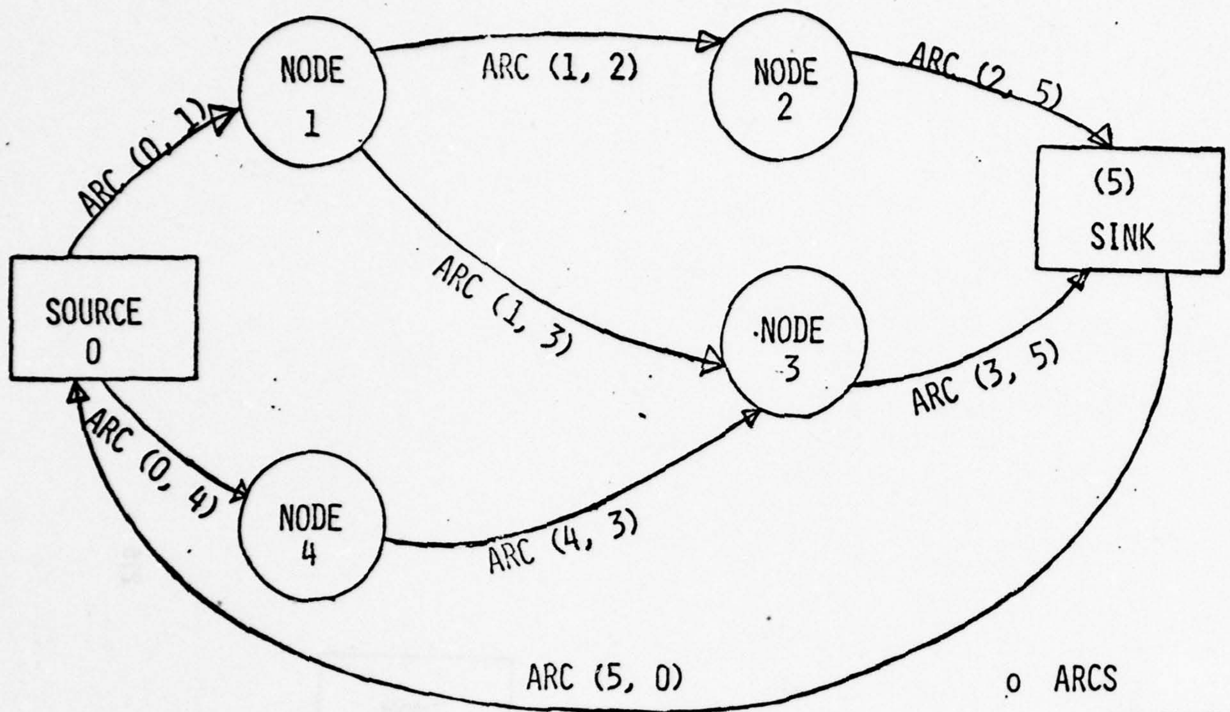
CHART 7

THE BID EVALUATION MODEL

(NETWORK GENERATION)

CHART 8

WHAT IS A NETWORK ?



- o ARCS
  - MINIMUM & MAXIMUM CAPACITIES
  - COST/UNIT OF FLOW
- o OBJECTIVE:

  FIND MINIMUM COST PATH THROUGH NETWORK

CHART 9

NOTATION

FOR

ARC FLOW RESTRICTIONS AND COSTS

CHART 10

CHART 11

There are two types of maximum offers. The first type concerns the total company. In this case, we specify an arc between the source and the company with the maximum amount that the company is willing to sell us as the only variable different from zero.

In addition, it is possible for a company to have a subset of bids which are restricted by some maximum amount. In this case, we create an artificial node and connect it with an arc from the company node. The restriction is represented by the maximum flow for that arc.

CHART 12

The minimum acceptable quantity bids are represented with the MAQ amount in the minimum field for the arc between a company or artificial node and the destination. The possibility of accepting nothing from that company is obtained by deleting the rejected arc. The method of deleting the arc will be explained in the mathematical description to follow.

CHART 13

Each origin bid generates several destination bids; the bid amount and MAQ are treated by using an artificial node. From this artificial node, a destination bid is generated for each possible delivery point. These bids do include cost - both the origin bid cost and the transportation cost - but do not constrain flows since this was done earlier.

CHART 14

This is the network for the example. Note the company restrictions in the arcs from the source to company 1 and from the source to company 2. In addition, notice the minimum acceptable quantities (MAQ) of 200 on the arcs from company 1(C1) to S1, A1 to B1 and D, C2 to D and B2, and C3 to B2. The minimum quantities of 500 and 600 from B1 and B2 to the sink force flow through the network. Our objective is to find the paths that will insure that 1,100 units flow into the sink in such a way that cost is minimized and all minimum and maximum flow constraints are satisfied.

CHART 15

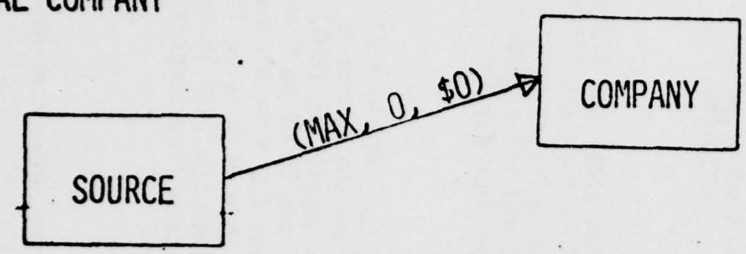
We are now going to mathematically model the network we have generated.

CHART 16

In the simplest formulation of the problem we ignore the minimum and maximum flow constraints on the arcs. Define X_K as the amount of flow over arc K; C_K as the cost per unit of flow on arc K; S as the set of all the arcs; B_i as the set of all arcs which connect nodes to the sink, that is, that connect the base nodes to the sink; and A_i as the set of all

MAXIMUM OFFERS

- o FOR TOTAL COMPANY



- o FOR 2 OR MORE BIDS FROM THE SAME COMPANY

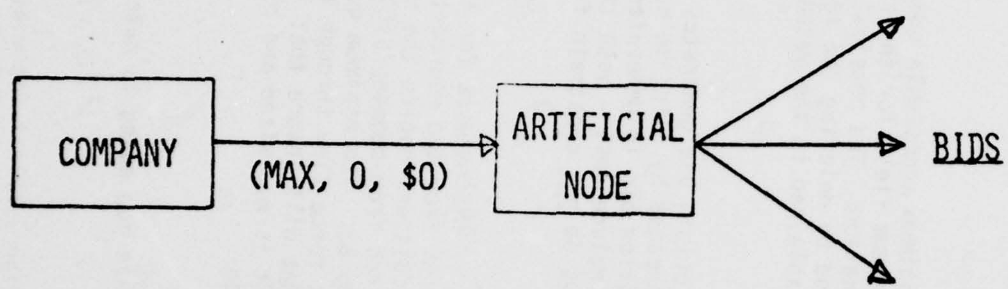
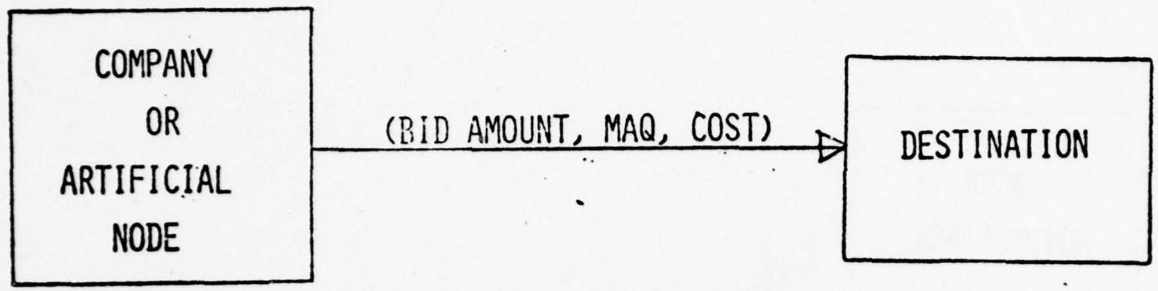


CHART 11

MINIMUM ACCEPTABLE QUANTITY (MAQ) BIDS

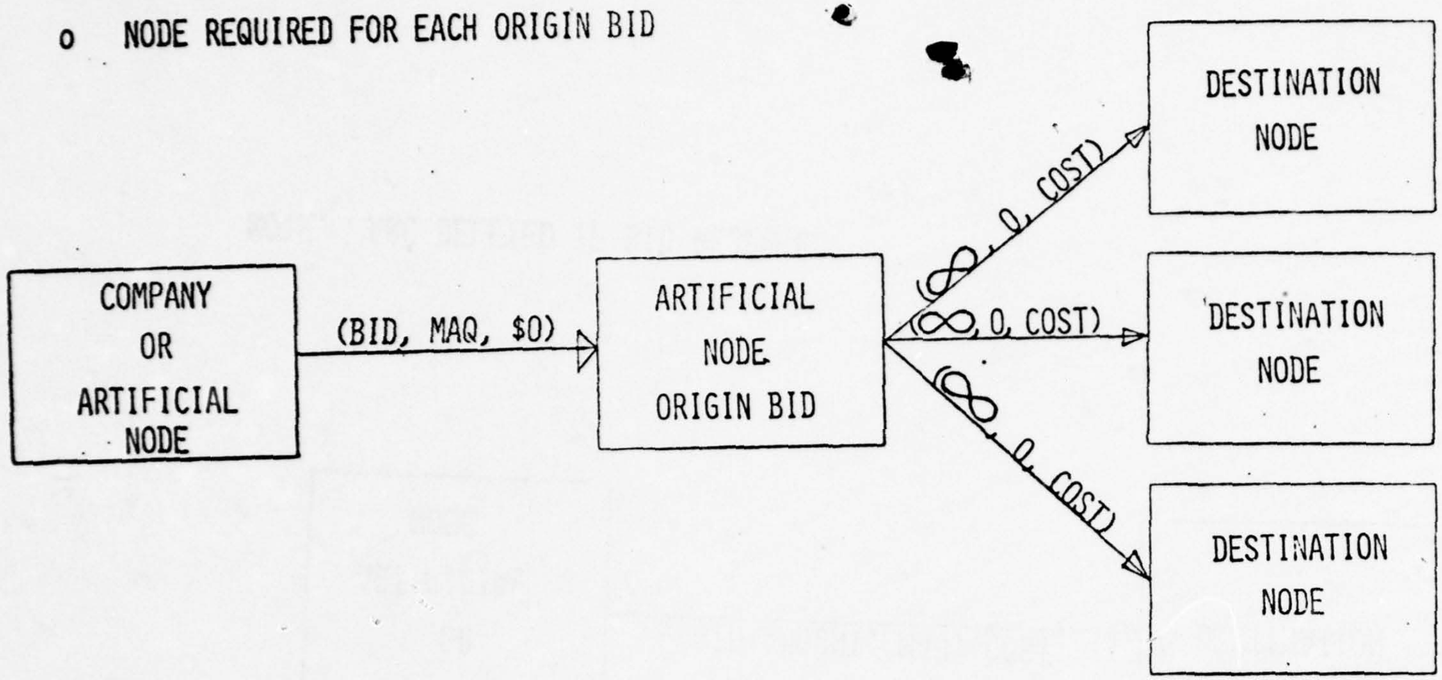


NOTE: ARC DELETED IF BID REJECTED

CHART 12

ORIGIN BIDS

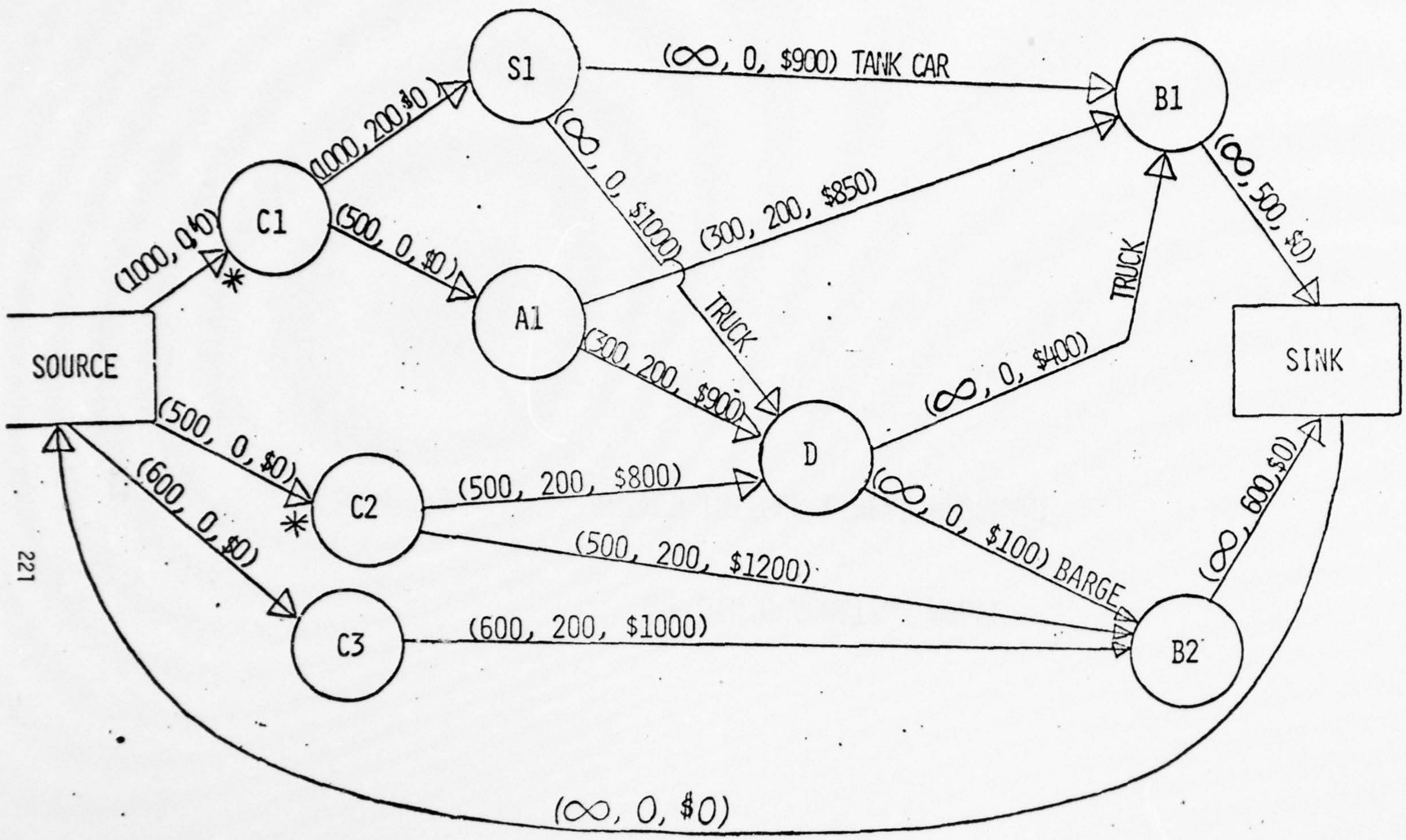
- o DESTINATION BIDS WITH DOD SHIPPING COSTS ADDED TO ORIGIN BID
- o NODE REQUIRED FOR EACH ORIGIN BID



COST = BID + TRANSPORTATION COST

CHART 13

NETWORK FOR EXAMPLE



* TIE-IN BID

(MAXIMUM AMT, MINIMUM AMT, COST/UNIT)

CHART 14

THE BID EVALUATION MODEL

(MIXED INTEGER LINEAR PROGRAM)

CHART 15

SIMPLEST FORMULATION OF PROBLEM

LET

X_k = AMOUNT OF FLOW ON ARC k.

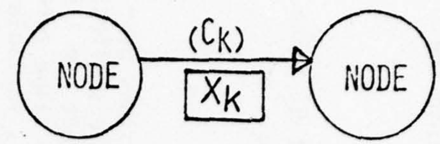
C_k = COST PER UNIT OF FLOW ON ARC k.

S = SET OF ALL ARCS

B_i = SET OF ALL ARCS WHICH CONNECT NODES TO SINKS

A_i = SET OF ALL ARCS WHICH CONNECT THE SOURCE TO NODES

ARC k



$$\underset{X}{\text{MINIMIZE}} \sum_{k \in S} C_k X_k$$

SUBJECT TO:

$$\sum_{k \in B_i} X_k - \sum_{k \in A_i} X_k = 0 \qquad \text{CONSERVATION OF FLOW CONSTRAINT}$$

CHART 16

arcs which connect the source to nodes (company nodes). Our objective is to find the values for the X_K's so as to minimize cost subject to the conservation of flow constraint. This constraint says that the amount that flows out of the source must equal the amount that flows into the sink.

CHART 17

X_1, X_2 and X_3 are in the set A_i; and X_{15} and X_{16} are in set B_i. The conservation of flow constraint requires that $X_1 + X_2 + X_3$ equal $X_{15} + X_{16}$.

CHART 18

In this representation, we will cover maximum and minimum flows over the various arcs but will exclude tie-in bids. Define L_k as the smallest amount that can flow over arc K and H_k as the largest amount that can flow over arc K. Z is a binary decision variable that takes on the value zero if an arc is deleted and one if an arc is to be included. This variable is used to model the minimum acceptable quantity restrictions. Q is the set of arcs with MAQ bids. We are still trying to minimize the total cost of the system by selecting appropriate values of our decision variables X and Z. Our constraints included the conservation of flow constraint. A constraint which specifies that we must be within our lower and upper bounds whenever we are in the set X-Q, that is in the set that does not include the MAQ bids. When considering the set that does include MAQ bids, we multiply the lower and upper bounds (L_k, H_k) by our binary variable Z_k. When Z is equal to zero the value of X_k is forced to be zero. When Z_k is equal to 1 then the MAQ constraint must be met.

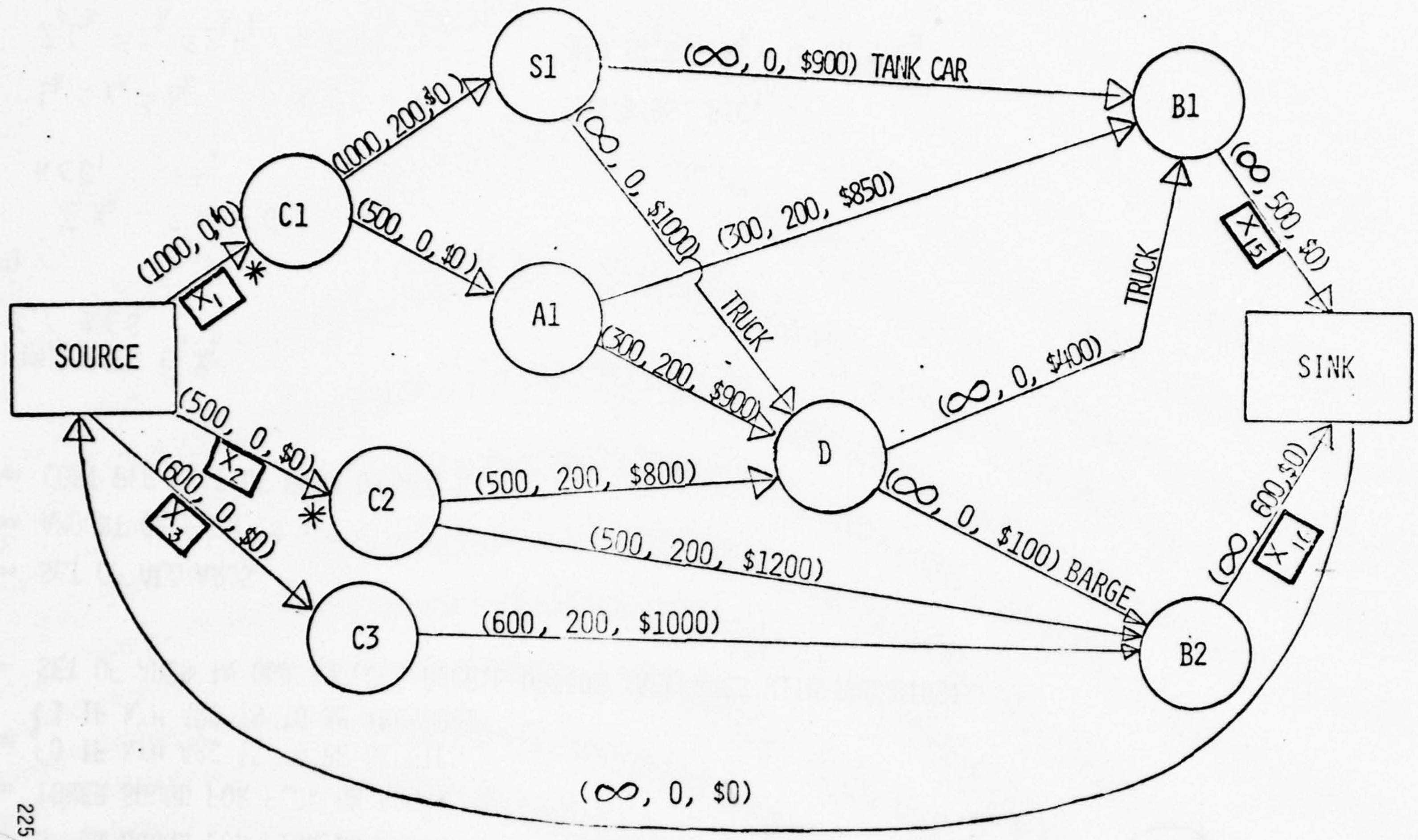
CHART 19

This chart represents the complete model including tie-in bids. Define M_j as the upper limit associated with the Jth tie-in bid, R_j as the set of arcs subject to that tie-in bid and P as the number of tie-in bids. The rest of the variables were defined previously. The objective function and the first three constraints were explained earlier. For a tie-in bid we have the total flow over the arcs associated with R_j being less than or equal to our upper limit, M_j. We have one of these constraints for each of the tie-in bids. In our example we have one tie-in bid between arcs X_1 and X_2.

CHART 20

This chart represents the network with its solution. The numbers in the boxes represent the flows over each of the arcs. For example, company 1 was awarded 500 units, 200 from their origin bid, and 300 from their destination bid to base 1; company 2 was awarded 400 and company 3 was awarded 200. All of the minimum acceptable quantity restrictions were satisfied. The total cost of the procurement was $995,000.

NETWORK FOR EXAMPLE



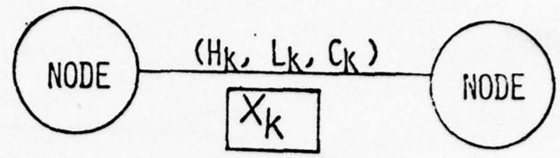
* TIE-IN BID

(MAXIMUM AMT, MINIMUM AMT, COST/UNIT)

CHART 17

INCLUDE ARC CONSTRAINTS
(MAX FLOWS & MAQ BIDS)

ARC k



LET

H_k = UPPER BOUND FOR FLOW ON ARC k

L_k = LOWER BOUND FOR FLOW ON ARC k

$Z_k = \begin{cases} 0 \text{ IF } k^{TH} \text{ ARC IS TO BE DELETED} \\ 1 \text{ IF } k^{TH} \text{ ARC IS TO BE INCLUDED} \end{cases}$

Q = SET OF ARCS IN OUR INCLUDE/DELETE OPTION (ALL ARCS WITH MAQ BIDS)

RECALL

S = SET OF ALL ARCS

X_k = AMOUNT OF FLOW IN ARC k

C_k = COST PER UNIT OF FLOW ON ARC k

THEN

$$\underset{X,Z}{\text{MINIMIZE}} \sum_{k \in S} C_k X_k$$

SUBJECT TO

$$\sum_{k \in B_i} X_k - \sum_{k \in A_i} X_k = 0$$

$L_k \leq X_k \leq H_k \qquad k \in S - Q$ MAX BIDS, ETC.

$Z_k L_k \leq X_k \leq Z_k H_k \qquad k \in Q$ MAQ BIDS: $X_k = 0$ OR $\geq L_k$

$Z_k = 0$ OR $1 \qquad k \in Q$

CHART 18

INCLUDE TIE-IN BIDS
(COMPLETE MODEL)

LET

M_j = MAXIMUM AMOUNT ASSOCIATED WITH j^{TH} TIE-IN BID RESOURCE CONSTRAINT

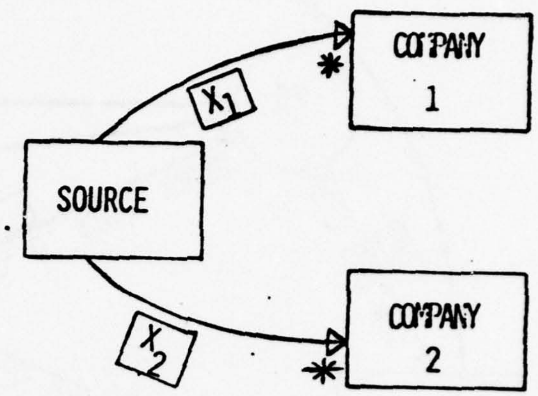
R_j = THE SET OF ARCS SUBJECT TO THE j^{TH} TIE-IN BID CONSTRAINT

P = NUMBER OF TIE-IN BIDS

RECALL L_k = LOWER BOUND FOR FLOW ON ARC k

H_k = UPPER BOUND FOR FLOW ON ARC k

$Z_k = \begin{cases} 0 \text{ IF } k^{TH} \text{ ARC DELETED} \\ 1 \text{ IF } k^{TH} \text{ ARC INCLUDED} \end{cases}$



* TIE-IN BID

$X_1 + X_2 \leq M_1$

__THEN__

$$\underset{X,\,Z}{\text{MINIMIZE}} \sum_{k \in S} C_k X_k$$

SUBJECT TO

$$\sum_{k \in B_i} X_k - \sum_{k \in A_i} X_k = 0$$

$$L_k \leq X_k \leq H_k \qquad k \in S - Q$$

$$L_k Z_k \leq X_k \leq H_k Z_k \quad k \in Q$$

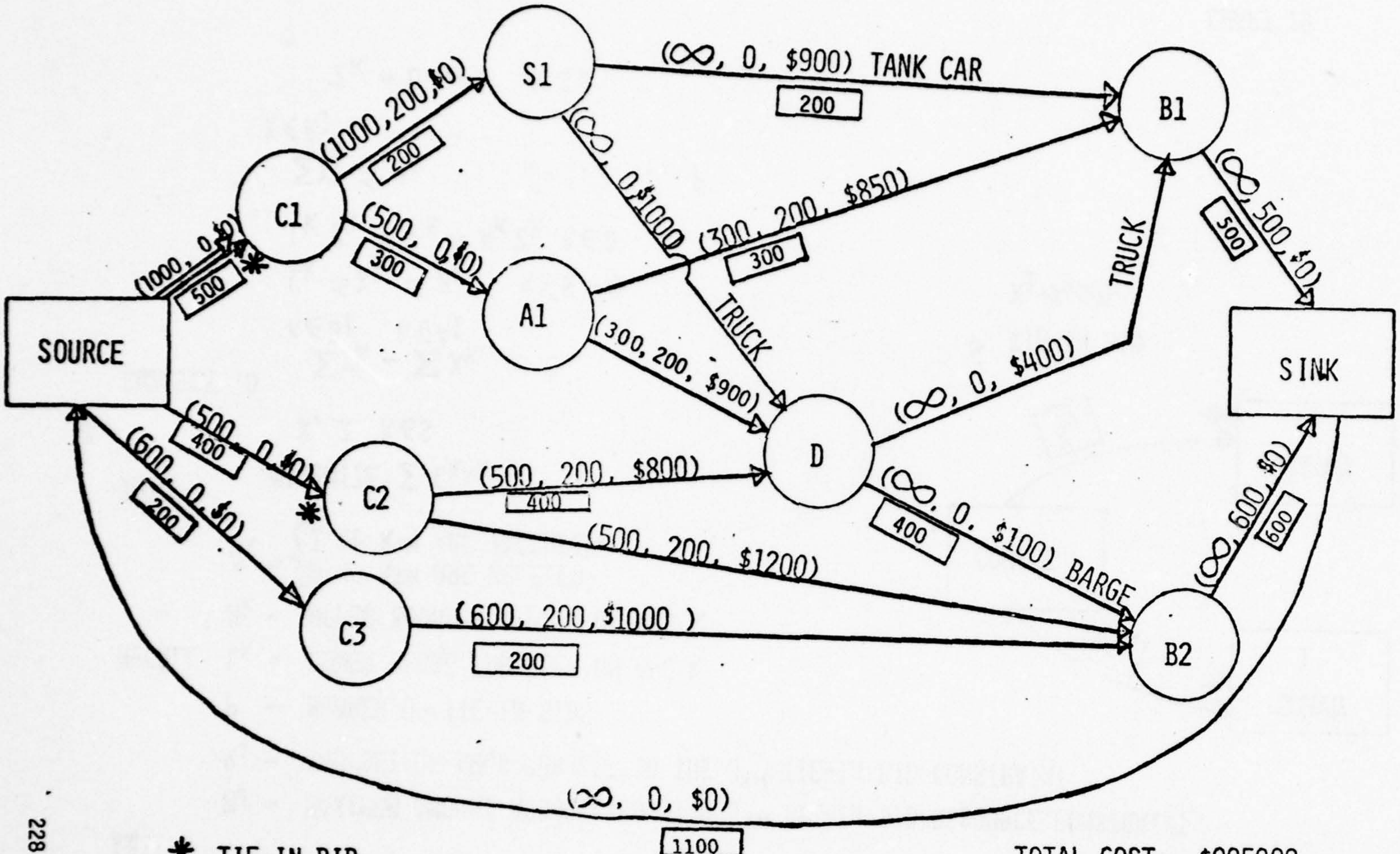
$$\sum_{k \in R_j} X_k \leq M_j \qquad j = 1, 2, \ldots. P$$

$$Z_k = 0 \text{ OR } 1 \quad k \in Q$$

CHART 19

SOLUTION

NETWORK FOR EXAMPLE



✱ TIE-IN BID

(MAXIMUM AMT, MINIMUM AMT, COST/UNIT)

TOTAL COST: $995000

CHART 20

CHART 21

The bid evaluation model allows the Defense Fuel Supply Center to determine the least cost solution for the procurement of petroleum products. The outputs of the model are used in the award process thus reducing the manual labor required in procurement. In addition, the output of the model provides a fuel distribution plan for a single product. Finally, the model serves as justification for bid selection with regard to inquiries from rejected contractors or the GAO.

BENEFITS DERIVED FROM USING BID EVALUATION MODEL

- DETERMINES LEAST COST SOLUTION FOR FUEL
- REDUCES MANUAL LABOR REQUIRED IN PROCUREMENT
- PROVIDES FUEL DISTRIBUTION PLAN
- PROVIDES JUSTIFICATION FOR BID SELECTION

CHART 21

DISTRIBUTION AND STORAGE SYSTEM ANALYSIS

by Major James Bexfield

CHART 1

This is an outline of the briefing.

First I will explain the purpose of the analysis, followed by a general discussion of the methodology which was tested in the northwest United States.

Next comes the conclusion followed by the plans we have for future analysis.

CHART 2

The purpose of the analysis was to compare the current distribution pattern with alternate distribution patterns.

In addition, we evaluated Defense Fuel Support Points (DFSP's) with respect to their capabilities (to include size, and transportation availability), location and number.

CHART 3

Our basic problem is one of getting product from the sources to the customers, usually through Defense Fuel Support Points.

Our objective is to determine the group of paths which minimize the cost of the distribution system while meeting all mission requirements.

CHART 4

To obtain this minimum cost solution, we use a technique called mixed integer linear programming.

In this model there are two types of decision variables - one type of decision variable is the amount of product flow by type over each path. A second type of decision variable is one which allows a terminal to be either open or closed. Associated with each terminal is a fixed cost which is avoided if a terminal is closed. This option can be especially useful in evaluating new terminal additions.

Our objective is to minimize transportation costs, fixed and variable terminal costs, and product costs.

OUTLINE

- PURPOSE
- METHODOLOGY
- RESULTS FOR NORTHWEST U. S. (TEST CASE)
- CONCLUSIONS
- FUTURE ACTIVITIES

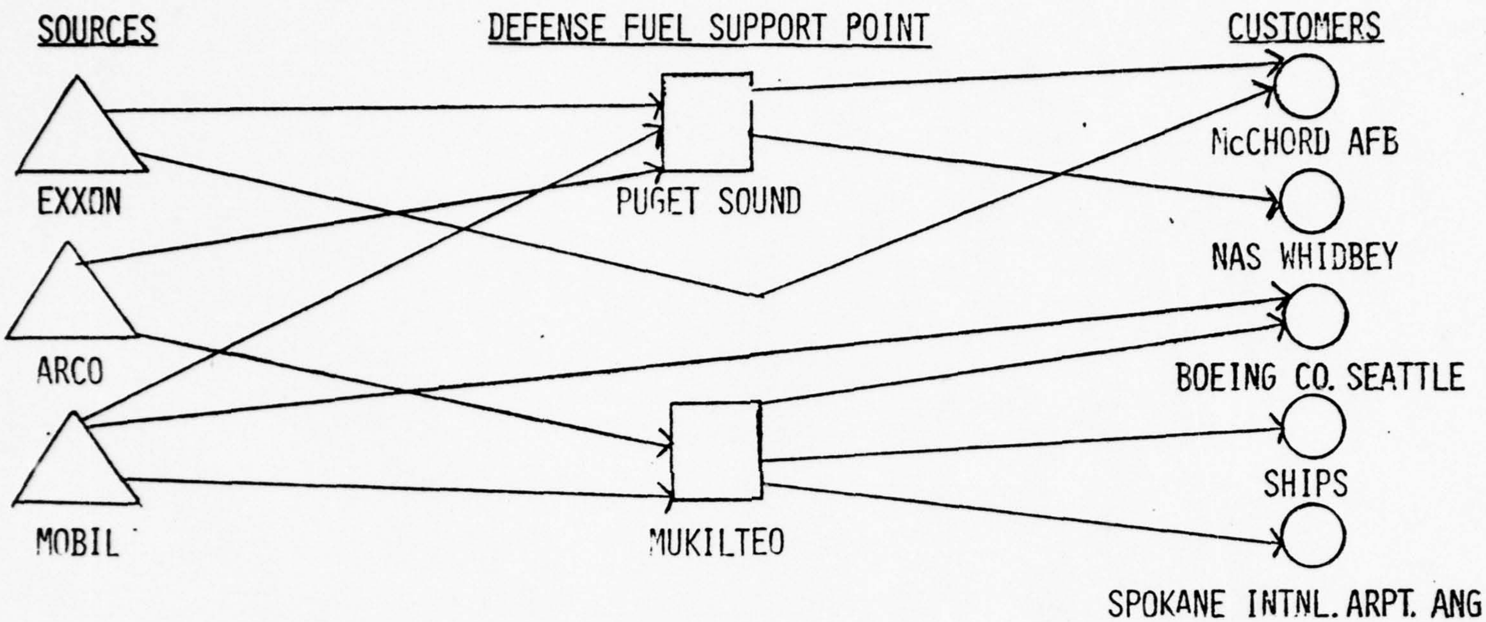
CHART I

PURPOSE

- EVALUATE THE ALTERNATIVE DISTRIBUTION PATTERNS
- EVALUATE DEFENSE FUEL SUPPORT POINTS (DFSP's) WITH RESPECT TO THEIR CAPABILITIES, LOCATION, AND NUMBER

CHART 2

THE PROBLEM



- SEVERAL PRODUCTS
- DIFFERENT MODES OF TRANSPORTATION
- CAPACITIES OF DFSP's BY PRODUCT

CHART 3

MIXED INTEGER LINEAR PROGRAM

- DECISION VARIABLES
  - PRODUCT FLOW BY PRODUCT TYPE
  - TERMINALS (OPEN OR CLOSED)
- OBJECTIVE FUNCTION

$$\text{MIN}\left[\begin{pmatrix}\text{TRANSPORTATION}\\ \text{COST}\end{pmatrix}+\begin{pmatrix}\text{FIXED TERMINAL}\\ \text{COST}\end{pmatrix}+\begin{pmatrix}\text{VARIABLE TERMINAL}\\ \text{COST}\end{pmatrix}+\begin{pmatrix}\text{PRODUCT}\\ \text{COST}\\ \text{(OPTIONAL)}\end{pmatrix}\right]$$

- CONSTRAINTS
  - LIMIT ON AMOUNT OF PRODUCT AVAILABLE FROM EACH SOURCE
  - REQUIREMENT TO SATISFY CUSTOMER DEMAND
  - RESTRICTION ON TERMINAL CAPACITY
  - INTEGER CONSTRAINT ON TERMINALS (OPEN OR CLOSED)
  - CONSERVATION OF FLOW
  - SPECIAL CONSTRAINTS

CHART 4

In doing this we must meet some constraints --

1. We must not overlift a contract.

2. All customer demands must be satisfied exactly.

3. Flow through terminals must not exceed their maximum through-put capabilities.

CHART 5

In our test case we considered the northwest United States. The maps of this area which you will see later in this briefing will not be to scale due to clusterings in the distribution system.

The following charts provide examples of the data used in this test case. (CHARTS 6-10: No script provided for these statistical charts).

CHART 11

Next we compared the actual distribution pattern vs the pattern generated by the linear programming model when the model was minimizing transportation, terminal and product costs.

The next chart describes the actual distribution pattern for FY 1976.

CHART 12

The dotted lines represent the source to terminal paths and the solid lines represent the terminal to customer paths. The numbers associated with each path (line) indicate the amount of JP4 (in thousands of barrels) that was sent over that path during FY 1976. The letters on each path refer to the transportation mode (TT = tank truck, TK = tanker, P = pipeline, B = barge, TC = tanker car). The circles, squares and triangles were used to identify the customers, terminals and suppliers (the numbers inside these symbols were used by the computer model). The symbol O is used to identify a pipeline terminal.

For example: 1,067,000 bbls was sent from FERNDALE through the BUCKEYE pipelines to McCHORD AFB.

CHART 13

This chart highlights the differences in flow (M bbls) between the actual pattern and the pattern suggested by the linear programming model. Paths that are eliminated are crossed out. Changes in amounts over a path are indicated by plus (+) and minus (-) quantities. These changes are of two types. The first type of difference is due to time sensitive product availability and requirements in a particular area. As an example of this, note the 8,000 bbls path from Mukilteo to Portland ANG. The other type of difference is substantive in nature. In this case there may be a reason to alter the basic distribution pattern. As an example, the LP

NORTHWEST CONUS

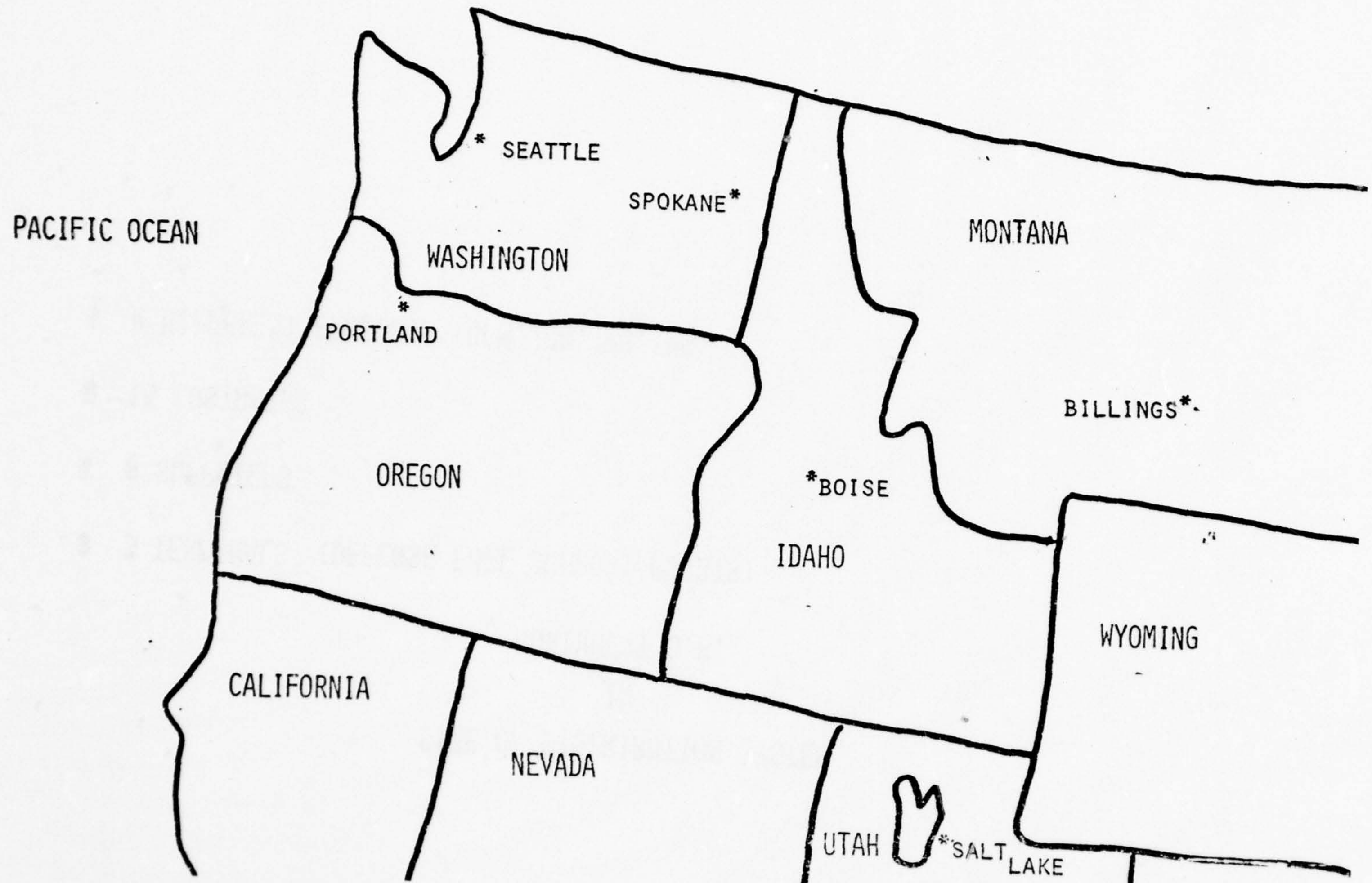


CHART 5

SIZE OF DISTRIBUTION SYSTEM
IN
NORTHWEST U.S.

- 3 TERMINALS (DEFENSE FUEL SUPPORT POINTS)
- 6 SUPPLIERS
- 15 CUSTOMERS
- 4 DIFFERENT PRODUCTS (DFM,JP4,JP5,145)

CHART 6

TERMINALS SERVING NORTHWEST U.S.

FY 1976

DFSP	MAX THROUGH-PUT (1000 BBLS YR)	COST ($1000 YR)
PUGET SOUND (GOGO)	1545	522*
MUKILTEO (GOCO)	1500	507
PORTLAND (COCO)	176	223

* ESTIMATED

CHART 7

SOURCES IN NORTHWEST U.S.

FOR FY 1976

- QUANTITIES (1000 BBLS)

SOURCES	JP4	JP5	DFM	145
EXXON	912			
ARCO	1237	864	834	239
MOBIL	2784	517		197
CHEVRON	636			
AMOCO	763			
PHILIP	223			

- PRICE RANGES (PER BBL)

PRODUCT	LOW	HIGH
JP4	12.13	13.60
JP5	12.40	13.24
DFM	12.14	12.14
145	14.52	15.82

CHART 8

CUSTOMERS IN NORTHWEST U.S.

DEMAND IN BBL

FY 1976

CUSTOMER	DFM	JP4	JP5	145
PUGET SOUND (SHIPS)	595,671		266,148	
PUGET SOUND (GEN)	4,168		11,435	
MUKILTEO (GEN)		5,617		8,807
PORTLAND A.N.G.		141,207		
SPOKANE INT. ARPT. A.N.G.		43,147		
McCHORD AFB		1,066,989		5,005
HILL AFB		643,118		
MOUNTAIN HOME AFB		706,756		
FAIRCHILD AFB		1,049,518		
KINGSLEY FIELD		22,942		
NAVAL SHIPYARD BREM.	50,476			
N.A.S. WHIDBEY IS.			65,949	13,466
BOEING CO. SEATTLE		46,869		
FT. LEWIS WASH.		9,760		
USPFO PB MILL DEPT. ORE		8,474		

CHART 9

TRANSPORTATION RATES

FY 1976

PRODUCT	SOURCE	DESTINATION	MODE	TRANS COST/BBL-
JP4	BILLINGS, MT	SPOKANE INT'L A/P ANG	PIPELINE	$ .5300
	BILLINGS, MT	FAIRCHILD AFB	PIPELINE	.5400
	CHERRY POINT, WA	MUKILTEO	TANKER	.2286
	CHERRY POINT, WA	PORTLAND	TANKER	.3353
	MULKITEO	PORTLAND ANG	TRUCK	1.8000
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"

CHART 10

ANALYSIS OF CURRENT DISTRIBUTION PATTERN

ACTUAL PATTERN

VS

PATTERN GENERATED BY LP MODEL

(BASED ON TRANSPORTATION,TERMINAL & PRODUCT COSTS)

CHART 11

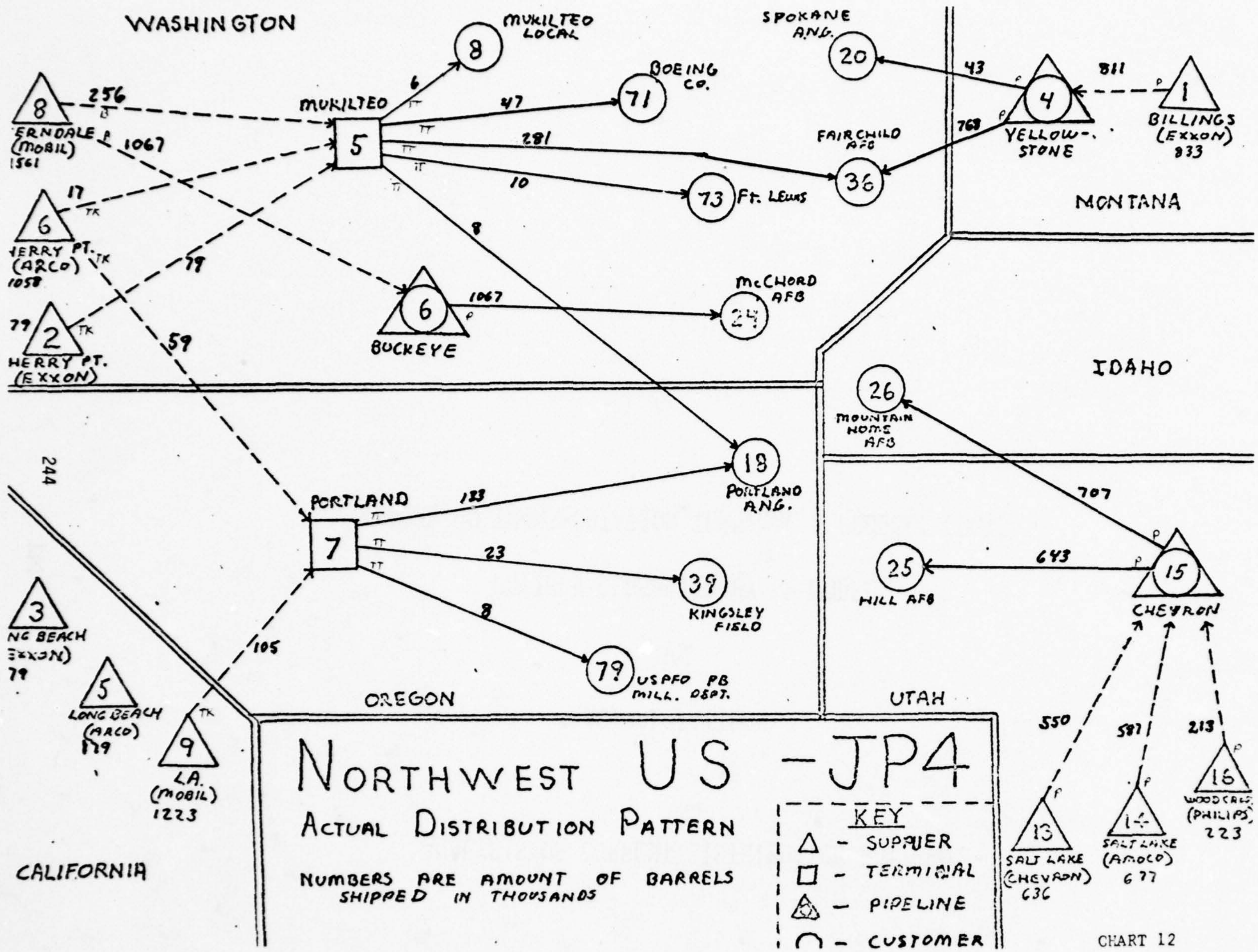
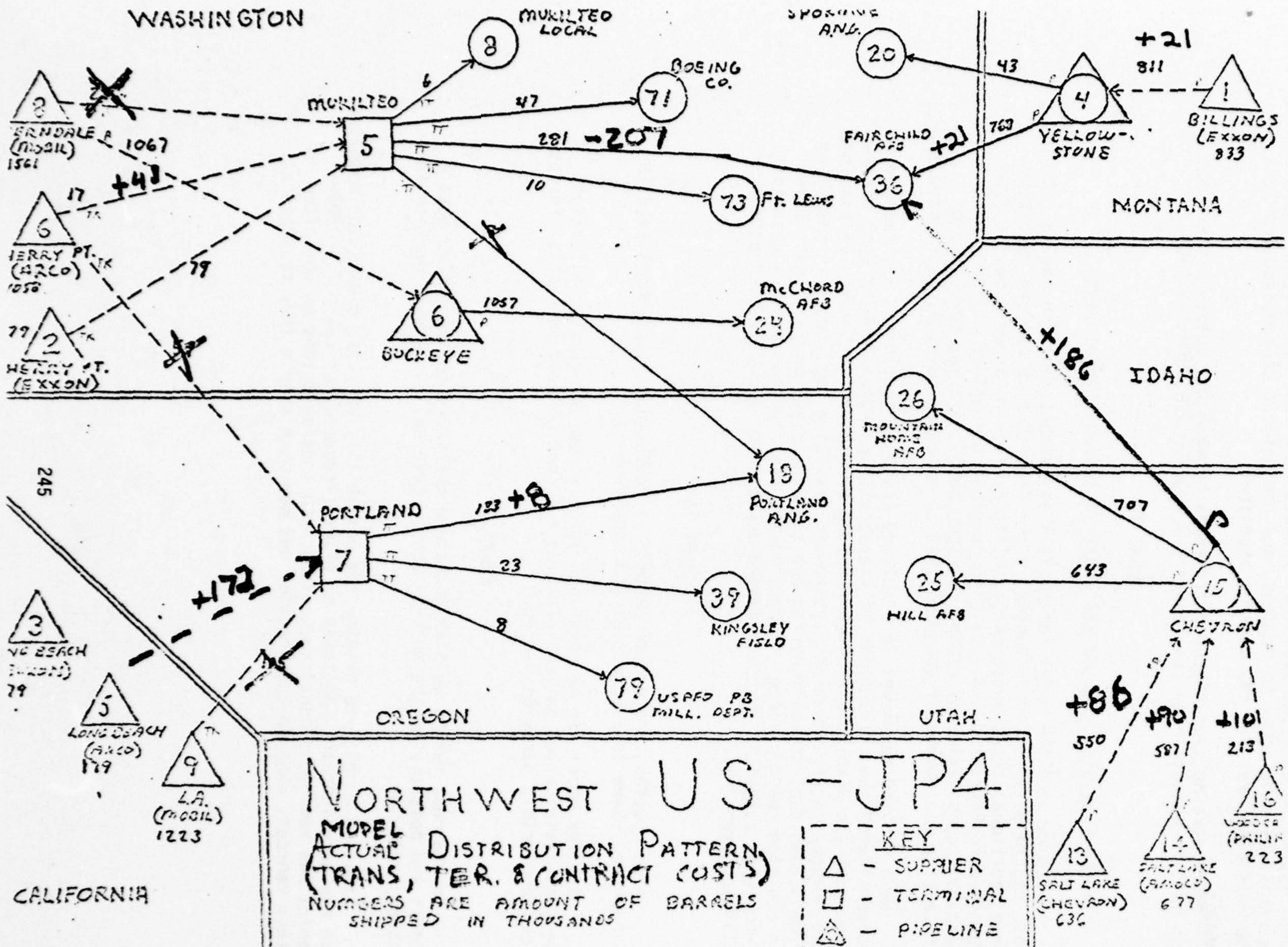

NORTHWEST US - JP4
ACTUAL DISTRIBUTION PATTERN
NUMBERS ARE AMOUNT OF BARRELS SHIPPED IN THOUSANDS
KEY
△ - SUPPLIER
□ - TERMINAL
PIPELINE
○ - CUSTOMER
WASHINGTON
OREGON
CALIFORNIA
MONTANA
IDAHO
UTAH
MUKILTEO
PORTLAND
FERNDALE (MOBIL) 1561
HERRY PT. (ARCO) 1058
HERRY PT. (EXXON)
NG BEACH EXXON) 79
LONG BEACH (ARCO) 179
L.A. (MOBIL) 1223
BUCKEYE
MUKILTEO LOCAL
BOEING CO.
FAIRCHILD AFB
Ft. LEWIS
McCHORD AFB
SPOKANE ANG.
YELLOW-STONE
BILLINGS (EXXON) 833
MOUNTAIN HOME AFB
PORTLAND ANG.
KINGSLEY FIELD
USPFO PB MILL. DEPT.
HILL AFB
CHEYRON
SALT LAKE (CHEVRON) 636
SALT LAKE (AMOCO) 677
WOODCROSS (PHILIPS) 223
256
1067
17
79
59
105
6
47
281
10
8
1067
133
23
8
43
768
811
707
643
550
581
213

CHART 12


NORTHWEST US - JP4
~~ACTUAL~~ MODEL DISTRIBUTION PATTERN (TRANS, TER. & CONTRACT COSTS)
NUMBERS ARE AMOUNT OF BARRELS SHIPPED IN THOUSANDS
KEY
△ - SUPPLIER
□ - TERMINAL
PIPELINE
○ - CUSTOMER
WASHINGTON
OREGON
CALIFORNIA
IDAHO
MONTANA
UTAH
MUKILTEO
PORTLAND
MUKILTEO LOCAL
BOEING CO.
FT. LEWIS
McCHORD AFB
BUCKEYE
FAIRCHILD AFB
SPOKANE ANG.
YELLOWSTONE
BILLINGS (EXXON) 833
MOUNTAIN HOME AFB
HILL AFB
CHEVRON
SALT LAKE (CHEVRON) 636
SALT LAKE (AMOCO) 677
PORTLAND ANG.
KINGSLEY FIELD
USPFD PB MILL. DEPT.
L.A. (MOBIL) 1223
LONG BEACH (ARCO) 179
(PHILIPS) 223
FERNDALE (MOBIL) 1561
FERRY PT. (ARCO) 1058
FERRY PT. (EXXON)
+21
+21
-207
+186
+48
+8
+172
+86
+90
+101
1067
1057
811
763
707
643
550
587
213
281
133
47
43
23
17
10
79
79
79
8
6
CHART 13

model suggested that the amount of product supplied from Mukilteo to Fairchild by tank truck be reduced, and the deficit be supplied from the Salt Lake area via the Chevron pipeline.

There were no significant differences between the actual pattern and the pattern suggested by the linear program for JP5, DFM and 145.

CHART 14

In the analysis, we used the model in two additional ways:

First we used the model for capital investment decision making. In this regard we considered changes in the distribution pattern resulting from additional transportation capabilities such as a new pipeline from Mukilteo to Fairchild AFB. We also examined the effect of increasing terminal capabilities by adding storage, building a new terminal, or increasing the number of products that an existing terminal can accommodate.

Next we used the model in simulated crisis situations. For example, we considered the elimination of transportation modes, due to such occurrences as the Mississippi River freezing or a pipeline break. We examined the changes in distribution pattern and resulting cost increase resulting from sudden contract elimination due to such things as a refinery fire. In addition, we considered changes in the distribution pattern resulting from large surges in customer demand due to, for example, unexpected military exercises.

CHART 15

In conclusion, the actual pattern is very close to LP model solution - however, there is a potential for some savings.

Also the model can be used in a large number of varying situations besides distribution pattern planning - it can be used in capital investment and crisis decision making.

CHART 16

In the near future we plan to extend the study to the entire west coast and possibly to the Houston area. Eventually, we will perform the study worldwide.

Finally, we plan to examine the possibility of using simulation modeling to evaluate inventory policies at DFSPs (frequency of reorder, reorder point and reorder amount) to include such considerations as how often do they reorder, when do they reorder and how much should they reorder?

ADDITIONAL ANALYSES

- CAPITAL INVESTMENT
  - ADDITIONAL TRANSPORTATION CAPABILITIES
  - ADDITIONAL TERMINAL CAPABILITIES
- CRISIS
  - ELIMINATION OF A TRANSPORTATION MODE AND/OR CONTRACT
  - SURGE IN CUSTOMER DEMAND

CHART 14

CONCLUSIONS

- ACTUAL PATTERN VERY CLOSE TO LP MODEL SOLUTION
- MODEL FLEXIBILITY

CHART 15

FUTURE ACTIVITIES

- EXTEND STUDY TO WEST COAST & POSSIBLY HOUSTON AREAS
- EXAMINE THE POSSIBILITY OF USING SIMULATION MODELING TO EVALUATE INVENTORY POLICIES AT DFSPS (FREQUENCY OF REORDER, REORDER POINT AND REORDER AMOUNT)

CHART 16

DICOMSS - Sort-on-Receipt Mechanization

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Pennsylvania

The Direct Commissary Support System (DICOMSS) is a DLA managed program designed to provide Brand Name and Specification Resale Subsistence to overseas military commissaries.

DICOMSS was conceived as a flow through system. The basic concept was that the commissaries would submit their requisitions monthly to a central procurement agency which would consolidate like requisitions prior to buying material from the vendors. The brand name material would then be shipped directly from the vendor to the commissary or to a CONUS supporting depot for consolidation into individual commissary shipments.

The consolidation is a Defense Depot Mechanicsburg Pennsylvania (DDMP) function. DICOMSS items are taken from the receiving vehicles and placed in storage locations. Receipt quantities are then confirmed to the center, the stock control point for DICOMSS. The center generates Material Release Orders (MROs) back to the depot. Based on the MROs, freight planning, order picking and seavan stuffing is accomplished.

The above procedures at the depot are accomplished by a manual, labor intensive operation. These manual procedures began when DICOMSS originally served six (6) European commissaries. DICOMSS currently serves 61 European commissaries. To improve the cost/performance of the DICOMSS function at DDMP, mechanization of the DICOMSS mission at DDMP has been under consideration since 1972. To support mechanization, a MILCON project was completed in December 1975. The MILCON provides 240,000 square feet of improved facilities in which to house mechanization.

Sort-on-receipt is not a new concept. It has been considered as an alternative to the present system since 1972. In its pure form it has not been a viable alternative due to its requirement for a pre-positioned MRO at the depot. Some administrators argue that this would in affect transfer center functions to the depot. This mechanized sort-on-receipt concept does not require a pre-positioned MRO or the transfer of any center functions to the depot. Some purists may even argue as to whether the term "sort-on-receipt" applies to this system.

This concept was developed by Mr. Christopher T. Flynn, formerly an Industrial Engineer at DDMP. A concept paper was prepared by him and is presently being staffed by DLA. Much of the material presented in this paper has been extracted from the concept paper.

In this concept material flows through seven functions. These seven functions are: receiving, segregation, sorting (order picking), palletizing and unitizing, holding and/or storing, stuffing, and transporting.

The most significant and beneficial change will be real time material receipt confirmation. Receiving will be accomplished in a well defined area adjacent to each receiving dock. Receiving clerks will observe material for visual damage and quantity verification. If, after inspection, the receiving action is to be delayed, the material is to be moved to facilities outside Building 506/507 for further evaluation. A data entry device (CRT) located in the receiving area will be used for a direct material receipt confirmation to t. data base at DPSC. Response to this entry will be a real time MRO. Response to this entry will also indicate the location in which this material will be placed.

Receipt of material requiring secured storage will occur at the north end of Building 506 at specially designated doors. Material will be off-loaded directly into the secured area. The capture of material receipt information will be exactly as described above by a CRT located in the secured area, the exception being that other than A condition code security items will remain in the secured area - with appropriate markings.

The Sort-on-Receipt function, segregation, is unique to this concept. Segregation refers to the computer decisions made, and physical handling of, the material from the time the data for the Material Receipt Confirmation (MRC) is entered into the computer until the material is ready for commissary sorting. There are several responses to the MRC. One response is the release of the MRO to the depot. This action permits segregation and billing to occur. Another response to the MRC is the direction the material will physically go as it leaves the receiving area.

It is the intent of this concept to take advantage of inherent characteristics of individual DICOMSS items. That is, by recognizing the compatibility, density, container type, condition code, and other special characteristics of an item, that item can be directed to the best handling/storage procedure. The three possible destinations of material leaving the receiving area are: (1) pre-sort hold area awaiting the mechanized sorter, (2) external to Building 506/507, (3) directly to post-sort hold areas (bypassing the sorter). The destination information will be computer printed on tickets which will adhere to the material.

The pre-sort hold area is to be physically adjacent to receiving areas. This storage is to be rack storage serviced by narrow aisle forklift trucks. This will allow maximum cube utilization and maximum visibility of this material. The location and identification of pallets in this area would be recorded in the central data base. It is anticipated that this temporary storage will contain 1,200 pallet openings, nominally one day's receipt.

The second destination, external to Building 506/507, would contain items not suitable to either mechanized sorting or storage in Building 506/507. Certain bagged items, such as flour and sugar, may not be suited to mechanized sorting. Additional items to be stored external to Building 506/507 are label items. Label items are items which, because of their chemical composition, are considered hazardous when shipped in the same seavan as other label items. These label items are expected to be 2 percent of the DICOMSS items. Segregating these items is primarily considered to facilitate freight planning and van stuffing.

The third destination for material leaving the receiving area is movement directly to the post sort hold area. The capability will be available in both the computer program logic and the materials handling equipment to bypass portions of the system. The intent of this capability is to recognize that individual commissaries order particular items essentially in the same pallet load quantities as the material is received. Although this situation may occur only on a limited basis, each occurrence can significantly reduce handling efforts. The computer controlled sorting operation performs the order picking function under this sort-on-receipt concept. That is, material is depalletized, counted, moved to distant location and palletized.

The sort operation will begin with a "call order" from a data terminal printer located at the sorter induction station. The order in which material is run through the mechanical sorter effects the efficiency of the manual palletizing function at the output of the sorter. Therefore, the computer will scan the items available in the pre-sort hold area so that each call order will maximize the volume of like items brought to the sorter. Like item selection refers to like compatibility codes, density codes, and container type.

Depalletizing will be accomplished with an assist from a mechanical aid. Several different techniques of depalletizing may be employed since the cases will not require any special orientation.

The sequentially numbered call order tickets will be provided to forklift drivers for bringing items to the depalletizing station. From the depalletizing station, cases will be placed on a conveyor awaiting sorter induction.

Induction into the sorter will take place in the sequence dictated by the sorter call order numbers. Induction will require one manual entry per call order - the NSN of the item. Computer logic will sort (order pick) the item by commissary to satisfy the MRO provided as a response to the MRC entry.

Item count will be by a mechanical device. Item quantity discrepancies, compared against the call order, will be flagged to the sorter operator via the data terminal at that station.

The specific equipment used to perform the mechanical sort can be of many different types. The concept defines sorter equipment capable of performing 120 sorts per minute and of handling the size and weight of the majority of DICOMSS items. This capability may be accomplished by a single high speed sorter or two or more lower speed sorters in parallel operation. Sorters may be of the tilt tray type, diverter type or other arrangements.

Sorter capacity of 120 sorts per minute is 50,400 sorts per 420 minutes (7 hour, usable) shift. This capacity is 120 percent of the average workload of 42,000 cases per day for a 12,000 Short Ton (ST) cycle. This workload will be further reduced by elimination of that portion that will not be mechanically sorted. Thus, the system is designed at peak. The sorter is expected to occupy the high bay section of Building 506.

Palletizing personnel will build pallets at the discharge chutes at the sorter. Pallets will be configured for shipment. Some partial pallets will occur. These pallets will be moved to the designated post sort hold area. Completely full pallets, nominally 48WX40LX43H, will be unitized before being taken to the designated location in the post sort hold area. Unitizing can be achieved by shrink wrap, stretch wrap, bonding, or strapping techniques. A general requirement is that all pallets, both complete and partial, would be squared to the pallet corners providing a flat top surface to permit stacking.

Palletizing will also require the generation of pallet identification tickets. These tickets will identify the quantity of items on a pallet, the compatibility code of the pallet, the density of the pallet, material RDD, and the designated commissary staging area.

One scheme for achieving this is to have a CRT display, in sequence, items available to the palletizer. At completion of a pallet, the palletizer would indicate with a marker (curser, light pen, etc.) the last item placed on the pallet. A hardcopy ticket would then be produced for attaching to the pallet. The ticket would be applied external to either stretch or shrink wrap.

Pallets, because of the volume used, possibly 2,000 per day, will be mechanically supplied to the palletizing stations. The palletizing stations will also benefit from mechanical aids. Such aids may include lift tables which may also rotate; back stops to positively form two sides of the pallet; gauges to indicate proper height and width of pallet loads, etc.

The post sort hold area will contain material processed only in Building 506/507. The post sort hold area is proposed to be a conventional unracked bulk storage area serviced from 12 foot aisles. The proposed storage pattern is unracked storage two pallets deep from all aisles. Storage height is proposed to be three or four full pallets high. The high bay area of Building 507 will allow storage at four pallets high. Canned goods will permit stacking to this height. Compatibility codes

and density codes will not be mixed in any stack/location. The entire post sort hold area will be serviced by conventional (on board) forklift trucks.

Sort-on-receipt freight planning consists of two phases. The first phase involves the decisions as to what quantity and type of freight for which commissary or commissaries should be consolidated for a seavan load. Freight planning in this concept may be entirely automated or may require the interaction of a freight planner with the computer through a real time data terminal. In either case, the decisions made will not be unlike those made in the current manual freight planning operation. The goal of this phase is the development of optimized seavan loads in terms of weight, cube and RDD requirements. This aspect of freight planning is referred to as "load configuration".

The second phase of freight planning involves the preparation of the shipping documentation that will accompany the material to the consignee. This documentation identifies the specific items loaded on the seavan, and will be prepared after seavan loading. This phase is referred to as "consist preparation".

Stuffing will begin with receipt of the Load Configuration Worksheet from freight planning. Complete pallets and partial pallets will be pulled from Building 506/507 as indicated. Material stored external to Building 506/507 and the security area will be order picked and sent to the shipping assembly area. These pallets will be consolidated and unitized as required. Pallet identification tickets will be forwarded to freight planning for consist preparation. The seavan will be stuffed, the required documentation attached to the material, and the van sealed.

Throughout this concept constant effort has been given to maximizing the use of space in the Building 506/507 complex. This effort will also be applied in the allocation of staging space to each commissary.

Because of the storage pattern employed, individual commissary post sort hold areas need not be in increments of 40 pallets--a nominal seavan size. The smallest assignable space can be in increments of 6 or 8 pallets depending on stack height.

Certain large commissaries receiving essentially a seavan a day could be assigned a relatively small amount of space, approximately 60 pallet spaces, adjacent to a shipping door. This arrangement will allow the expeditious outloading of this material on an 'as accumulated' basis. In certain situations material for this class of commissary may be loaded directly from the palletizing operation.

The effort of this direct or nearly direct outloading will be to reduce overall space requirements. Potentially 30 percent of the seavans shipped fall into this category. That is, perhaps 600 pallet storage spaces will be all the space required for this continuous moving of 30 percent of the DICOMSS workload.

As described above, this concept creates the capability of outloading upon receipt in certain cases. Analysis of the DICOMSS customers indicates that a minimum of 5 and a potential of 10 customers fall into this category.

This potential is not assumed in any of the following discussions of pallet staging capacity. Analysis of receiving patterns will dictate the extent to which this direct loading can be achieved.

A recent development is the potential of supporting Middle East commissaries directly from CONUS via air delivery. Because of the size of the air pallets, this material would be stored external to Buildings 506/507 after sorting. Currently, this material is part of the depot workload going to GRSA. This development will further reduce the space requirements of Building 506/507.

The maximum pallet storage capability of Building 506/507 as described in this paper is estimated at 14,000 full pallets. Due to the constraint that this will be non-racked storage, partial pallets will not significantly affect maximum cube utilization.

The 14,000 pallet capacity represents 350 seavan loads at 40 pallets each. Approximately 15 percent of all material will be stored external to Building 506/507 by design. Therefore, this storage plan provides the ability to stage over 400 seavans. Further, all of this material is eligible for shipment immediately.

Personnel requirements are estimated at 130 for this concept. A manual/current system requires 160 personnel to accomplish the mission for the design volume of 12,000 ST/cycle. The annual savings produced by this reduction of 30 personnel will be $405,000.

Resource requirements are estimated between 1.8 and 2.0 million dollars. Based on this cost and the above annual savings, the payback period for the system will be 4.4 years.

An alternate system, Storage and Retrieval, being considered by DLA has a cost of 4.3 million dollars. The Sort-on-Receipt concept is the least expensive of all systems proposed to date.

DICOMSS requires a management information system (MIS) and a material control system (MCS). This system is needed now--but not provided. A MIS should have the ability to provide information for three critical types of decisions. The first decision is the current status of activity. The current status of activity is a comparison of what should be and what is against a short term cycle plan. A second requirement is to reflect what has happened. This provides insight so that management emphasis can be applied to critical areas. The third requirement is to project the future. Anticipation and planning are the significant objectives of senior management. The ability to see into the future in an organized predictable manner can prevent or minimize adverse impacts on the system.

A material control system (MCS) is different than a MIS. The objective of a MCS is to provide the same controls to DICOMSS material as that afforded other DLA-managed commodities. However, MOWASP, the vehicle of material control for other DLA commodities, was designed to control inventoried stock. Thus, DICOMSS is a poor fit to MOWASP. The MOWASP System is based on the fact that DLA operates under a centralized inventory accounting and requisition processing system. True--except a poor fit is created as DICOMSS is a purchase to order, not an inventory system. MOWASP provides for the traditional functions of warehouse/inventory management. Again, these management/inventory control procedures fit very poorly to DICOMSS, the non-inventoried commodity. Providing a suitable MCS to DICOMSS is an objective of this concept.

Since there is a definite differentiation between the functional areas supported by DDMP and DPSC, it is proposed that each activity be provided with a mini-computer. The mini-computer at DPSC would support unique center functions such as requisition processing, procurement MRO preparation, billing, etc. Input/output would be accomplished thru data display terminals located throughout DPSC's DICOMSS operation. It is estimated that DPSC may require as many as fifteen terminals.

The mini-computer at DDMP would provide the depot with such support as extracted contract information, issued MROs, segregation, sorting, palletizing, staging, freight planning, loading shipment confirmation, etc. Input/output would be accomplished by data display terminals located throughout DDMP's DICOMSS operation. It is estimated that DDMP may require as many as forty terminals.

The mini-computers will be interfaced with existing supply systems of each activity as required for exchange of data. The DPSC mini-computer will be interfaced with the DDMP mini-computer on a real time basis. Functional files maintained at each mini-computer will contain some common data and some data which pertains primarily to that activity. The terminals will have a real time interactive capability with the activity's mini-computer. Functional files will be on-line at each mini-computer.

Each mini-computer would provide MIS and MCS as previously described. MIS and MCS peculiar to each activity will be tabulated by the activity's mini-computer on a regular basis. Overall DICOMSS MIS and MCS requiring data extraction from both DDMP and DPSC files can be programmed as necessary with output at either location.

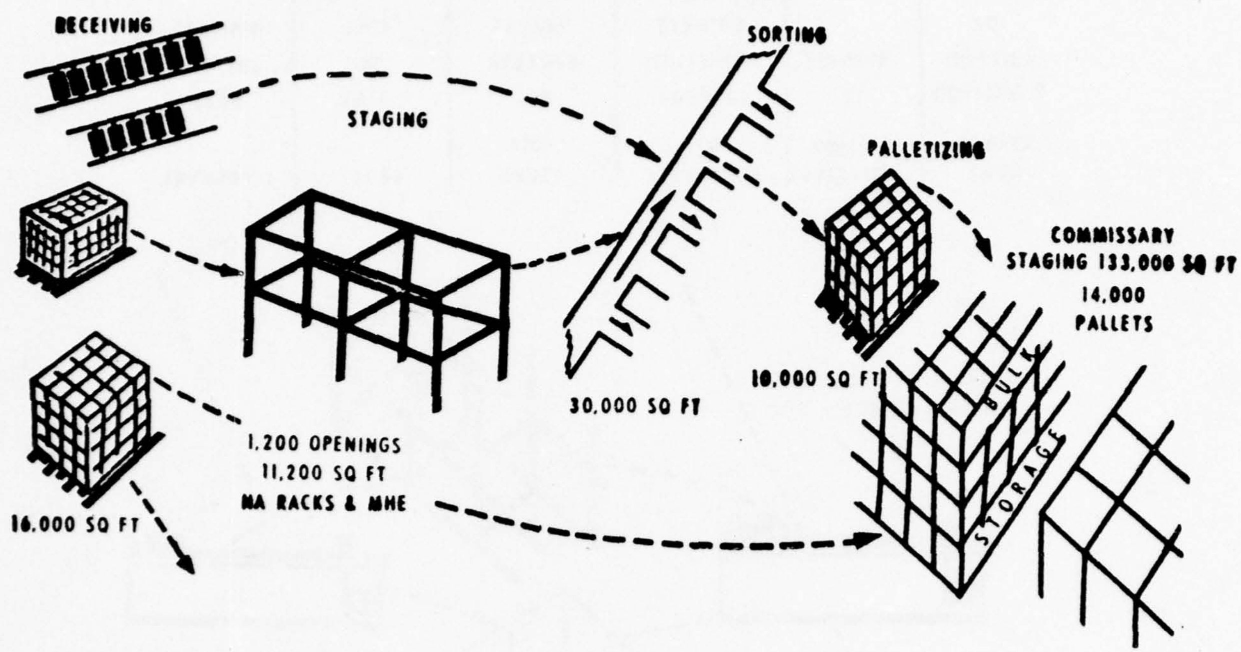
Obvious advantage is a faster response time between DPSC and DDMP for each of the required functions. The real time capability will provide a reduction of order ship time of approximately eight days. This equates to a reduction of some 4,000 tons of material at DDMP. The releasing of valuable storage space will improve accuracy, topped off by overall personnel savings.

A requirement for optimum system design is to investigate the workload through operations research (OR) techniques. Statistical techniques can identify homogeneous subsets of the existing workload. Forecasting methods can provide a predictable look into impacts of expected workloads. Queuing theory can illustrate the effects of subsystem failures or workload fluctuations.

Simulation, one of the most powerful and easy to use OR techniques, can provide insight into system behavior under many different sets of constraints.

The decision to use any or all of the above is dependent on many factors--the two prominent factors being time and money. Other factors are personnel resources and procurement policies. Personnel resources can be acquired both internal to DLA and external to federal service. The method/expectations of procurement will govern, to a degree, the amount of parameter analysis that it is desirable to perform in-house.

MATERIAL FLOW 506/507

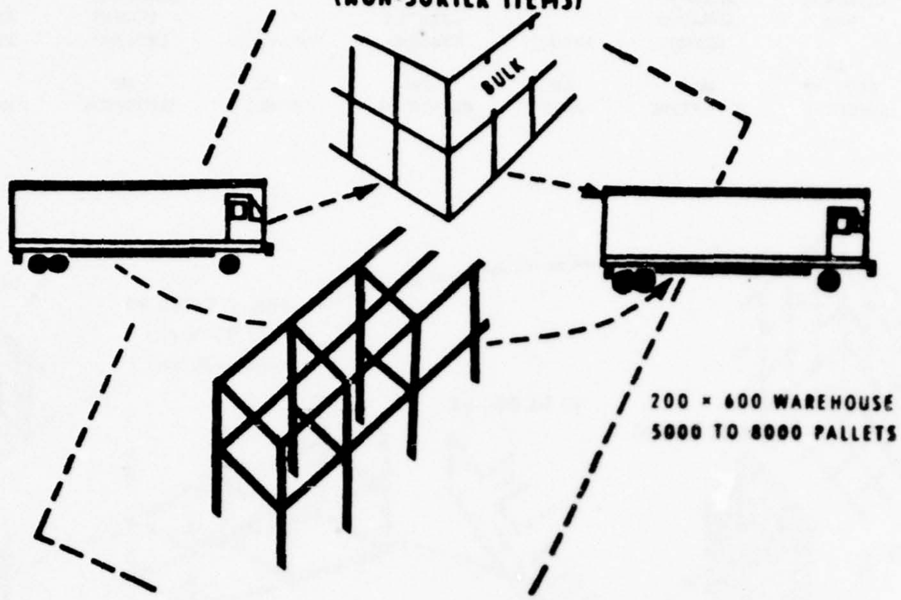


RECEIVE	IDENTIFY BY	SEGREGATE BY	STAGE BY	TO SORTER BY	SORT BY	PALLETIZE FOR	IDENTIFY PALLETS BY	CMMSRY STAGING BY
COUNT RECORD	CMPTBLY DENSITY NSN QUANTITY LOCATION	CMPTBLY LABELS OUTSIZED BAGS EXCESS FULL PALLETS	LOCATION	CMPTBLY DENSITY FAMILY NSN	CMMSRY	CMMSRY CMPTBLY DENSITY	NSN QUANTITY	CMPTBLY DENSITY

FULL PALLETS ⟶ (STAGE)

CHART 1

MATERIAL FLOW
(NON-SORTER ITEMS)



TRANSPORT	STORE	ORDER PICK	TRANSPORT TO	PALLETIZE UNITIZE	LOAD SEAVAN
FROM 506/507 RECEIVING	BULK OR RACK	FOR PLANNED SEAVAN	506/507 SHIPPING STAGING AREA	AT STAGING	CONFIRM & IDENTIFY TO CONSIST

CHART 2

PERSONNEL REQUIREMENTS

(12,000 ST/CYCLE)

	MANUAL	S-O-R
RECEIVE		
RECEIVING CLERKS	4	8
OFFLOAD/STORE/STAGE	37	14
RETRIEVE & DEPALLETIZE		22
SORT		2
ISSUE		
ORDER PICK	42	
PALLETIZE		25
STAGE		17
SECURITY ITEMS		5
ISSUE/SHIP		
SHIP		
FLOS	49	17
OTHER	10	
DICOMSS DIRECT SUPPORT OVERHEAD	18	18
MAINTENANCE		2
	160	130

CHART 3

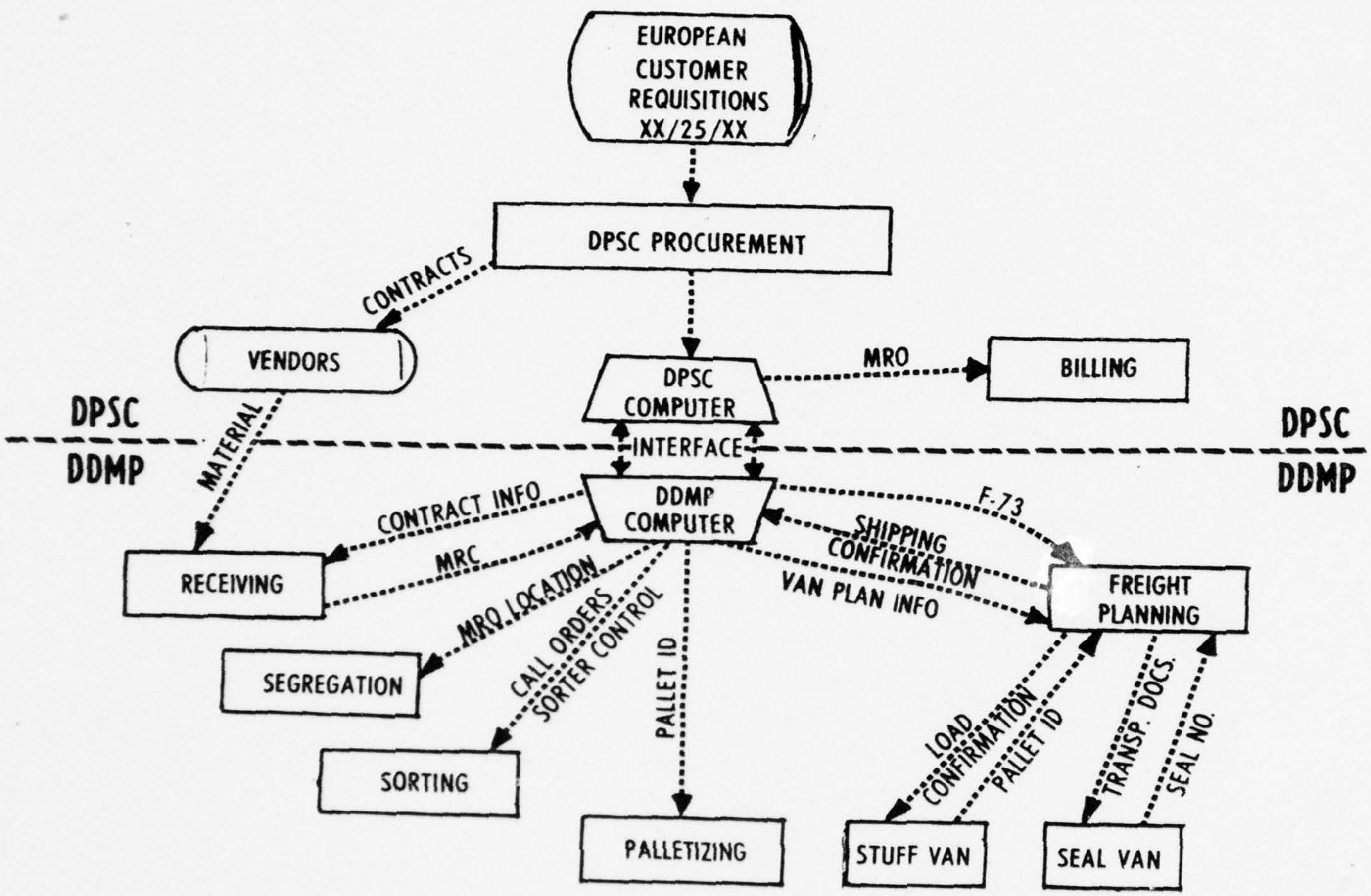
FUNDING REQUIREMENTS

	FUNDS
A. UTILIZE BUILDINGS 506/507	NO COST
B. RACKS	NO COST
C. NARROW AISLE FLT 28 EA	700,000
D. MINI-COMPUTERS	800,000*
E. SORTING EQUIPMENT	250,000
F. ADDITIONAL MATERIAL HANDLING EQUIPMENT	50,000
	1,800,000

*INCLUDES COST OF TWO MINI-COMPUTERS, PROGRAMMING OF MINI-COMPUTER, AND INTERFACE/COMMUNICATION BETWEEN DDMP/DPSC.

CHART 4

SORT-ON-RECEIPT DATA FLOW



COMPUTER OUTPUTS ARE REAL TIME INCREMENTS

CHART 5

REFLECTIONS ON DETERMINING
AN OPTIMAL DLA DEPOT
SCENARIO

(Robert C. Bilikam)

1. Background:

The DLA Depot Consolidation Study (April 1977) recommending consolidation of the DESC Depot function at other locations, along with previous studies of the Depot distribution and storage function (such as the DESC Electronics Distribution Study of 1973) prompted the rebuilding of the model on which the cost benefits were examined. This process brought to light certain characteristics of the problem recognized in the Electronics Distribution Study, and absent in traditional approaches using a strict linear programming transportation problem approach based on issue pattern.

2. Problem Description:

The initial approach to describing a method of assignment of issues to different depots simply consists of defining the costs to issue material to a customer area from each depot, and then assigning the optimal depot is the combination. However, the costs involved become defined by interrelationships which affect the solution to the problem.

a. Issue cost of transportation is affected by arrangements in the distribution pattern which can add to the transportation cost but save cost in receipt of the material from suppliers which must be redistributed from the depots. For example, material can be issued from one depot where it is received and received by another depot at less cost than a split shipment to both depots. Here direct labor and transportation costs are traded off against multiple shipment charges by suppliers, which must perform similar services at a price.

b. Receipts consist of customer returns and procurement quantities. The returns are received primarily from the customer areas to which issues are sent, whereas the production pattern of suppliers by state has no relation to customer demand. Therefore two entirely different receipt mechanisms determine the number and origin of

receipts experienced. The transportation costs and direct labor for procurement receipts depend on the location of the depots and how many depots there are. To build a factor for the LP problem to be solved by assigning issues from depots, the configuration of the depots must be considered in advance, thus making a number of alternative solutions to the LP problem necessary.

c. Finally the add on cost of split shipment charges and duplicate bin cost implied by each alternative must be examined. These costs can be a very large part of the total cost of an alternative, and cannot easily be described in the basic LP problem solution. Careful examination of receipt history is required to determine each of these costs.

d. The examples provided by the LPO briefing were intended to illustrate the affect of these complexities in determining the overall cost of a given distribution system.

3. Conclusion:

The simple theoretical framework of the LP solution to the distribution and receipt problem for a number of alternative depots is altered by a large number of practical considerations about where and how the receipts are obtained to fill issues, and what costs are incurred in distributing materials to our customers. In some cases the costs cannot even directly be entered into the LP solution, but must be accummulated for a given alternative. The fact that some costs have imprecisely fixed values does not preclude their existence. The best value for the costs obtainable must be used in order to arrive at a reasonable cost estimate of the different alternatives.

REFLECTIONS ON DETERMINING OPTIMUM DLA DEPOT SCENARIO

PREPARED BY
OPERATIONS RESEARCH AND ECONOMIC
ANALYSIS GROUP

DESC-LPO

INTRODUCTION

TRADITIONAL TRANSPORTATION MODEL

* DEMAND SOURCES - AREA (STATE)

* RECEIPT SOURCES - AREA (STATE)

    PROCUREMENT (SUPPLIERS)
    RETURNS (CUSTOMERS)

* TRANSPORTATION COSTS

    TO CUSTOMERS (DEPOT - STATE)
    FROM SUPPLIERS (STATE - DEPOT)
    DEPEND UPON DEPOT CONFIGURATION

* OTHER COSTS

    ISSUE COSTS - CONSTANT
    RECEIPT COSTS - DEPEND UPON DEPOT CONFIGURATION

EXAMPLE 1

COMMODITY: ELECTRONICS

(COSTS IN $1000)

SINGLE DEPOT

COSTS	TYPE	QUANTITY
$10,803	DIRECT LABOR ISSUE	4,270,000 ISSUES
3,051	DIRECT RECEIPTS	117,170 PROC. RCPTS.
9,509	TRANSPORTATION	(ISSUES/RECEIPTS)
0	SPLIT SHIPMENTS	0 SPLIT SHIPMENTS
0	DUPLICATE BINS	0 DUPLICATE BINS
$23,363		

EXAMPLE 2

COMMODITY: ELECTRONICS

(COSTS IN $1000)

THREE DEPOTS

ISSUE MATERIAL FROM PRIMARY DEPOT

COSTS	TYPE	QUANTITY
$10,894	DIRECT LABOR ISSUE	4,305,940 ISSUES
3,362	DIRECT LABOR RECEIPTS	117,170 PROC. RCPTS.
9,527	TRANSPORTATION	(ISSUES/RECEIPTS)
-0-	SPLIT SHIPMENTS	0
4,392	DUPLICATE BINS	209,959 BINS
$28,175		

EXAMPLE 3

COMMODITY: ELECTRONICS

(COSTS IN $1000)

FIVE DEPOTS

COSTS	TYPE	QUANTITY
$10,803	DIRECT LABOR ISSUE	4,270,000 ISSUES
3,947	DIRECT LABOR RECEIPTS	220,244 PROC. RCPTS. (ISSUES/RECEIPTS)
8,772	TRANSPORTATION	
3,297	SPLIT SHIPMENTS	86,756 SPLIT SHIPMENTS
8,796	DUPLICATE BINS	420,444 DUPLICATE BINS
$35,615		

CONSIDERATIONS NOT OPTIMIZED BY TRANSPORTATION MODEL

1. RECEIPTS DEPENDENT ON DEPOT CONFIGURATION/NUMBER

2. OTHER COSTS NOT DEPENDENT ON DEPOT-STATE ASSIGNMENT
   * COST SPLIT SHIPMENT
   * COST DUPLICATE BINS
   * OTHER METHODS - RECEIPT/ISSUE
   * ADDITIONAL TRANSPORTATION COST

3. MUST CAPACITATE TRANSPORTATION PROBLEM
   * DEMAND DETERMINED BY ITEM PLACEMENT
   * DETERMINE ISSUE/RECEIPT FACTOR
   * MUST RUN ALL FEASIBLE ALTERNATIVES

ECONOMIC RETENTION LIMITS

by
John W. Melone

The purpose of this presentation is to inform the DLA OR community of some recent modelling efforts on the subject of economic retention limits (see Chart 1).

Retention limits, which may be defined as upper limits on the stockage quantity permissible for any DLA item, have been a frustrating management decision problem for a number of years. Depending on assumptions about future needs and interpretations of the economics of DLA stockage, opinions have ranged from practically unbounded retention limits (keep all we have, we may need it) to fairly austere limits of the order of 2-3 years stock (the stuff probably will never be demanded in today's environment, so get rid of it).

The DLA has been using a limit of six years stock as a general retention limit for all commodities. This limit is relatively subjective - that is, it is based on subjective opinion about uncertainty in the demand rate - the probability of eventually issuing stock in excess of the six-year quantity appears sufficiently small to warrant disposal, thus saving some holding costs, even though there is some risk that the stock may have to be repurchased at a later date.

The DLA OR&EA Office performed a study on this subject in 1971. The study basically compared the cost rates of holding versus repurchase of a marginal unit of stock and concluded that general retention limits in the range of 4-8 years were applicable to DLA items, depending on the obsolescence periods assigned to DLA commodities. Although the model correctly formulated the economics of the decision problem, some of its assumptions have been questioned. The model assumed a deterministic demand pattern for DLA items and used procurement cost rates rather than actual costs in measuring the cost of repurchase. Recently, there has been some additional criticism (not necessarily directed at the model) within DLA of the general concept of a retention limit - it has been suggested that since storage cost rates are so modest, and since no one can guarantee that stock will not be demanded, - that "a priori" we should keep it. The current modelling effort has made some attempt to correct the perceived deficiencies in assumptions of the original study effort and to quantify the probability of demand.

The current OR study effort (see Chart 2) on retention limits is a theoretical one focusing on three main factors which simultaneously determine the value of the retention limit - the demand probability for

CHART 1

ECONOMIC RETENTION LIMITS

- UPPER LIMITS ON ITEM STOCKAGE QUANTITY
- CURRENT LIMIT 6 YEARS
- SUBJECTIVELY DETERMINED
  - SUBJECTIVE ESTIMATE OF DEMAND PROBABILITIES
  - UNQUANTIFIED RISKS
- OR ANALYSIS IN 1971
  - RECOMMENDED LEVELS IN RANGE 4-8 YEARS
  - DETERMINISTIC
  - USED PROCUREMENT COST RATES

CHART 2

CURRENT OR STUDY EFFORT

- RE-EXAMINE ECONOMIC RETENTION CRITERIA, USING FOLLOWING CONCEPTS:
  - DEMAND PROBABILITIES
  - REPURCHASE COSTS
  - HOLDING COSTS

DEMAND PROBABILITIES

- NO LONG-TERM DEMAND DATA IN DLA
- THEORETICAL WORK ON DEMAND PROBABILITIES IN ITEM STOCKAGE MODEL (POISSON DEMANDS)
- REEVALUATION OF VARIANCE TO MEAN SQUARE REQUISITION SIZE RATIO (DISC SAMPLE)
- ASSUMPTION OF LONG-TERM TECHNOLOGICAL REPLACEMENT PROCESS FOR EACH ITEM (VARYING RATE)

a given amount of stock on hand, the forecasted repurchase cost if the demand materializes and we have disposed of the stock, and the holding costs of DLA materiel. The net return from disposal is assumed to be zero.

Estimating the demand probability is the biggest problem. There are simply no long-term demand profiles for DLA items. Other than maintaining at most a two-year demand history for any item, only the date of last demand is known. So the approach to the estimation of demand probability has necessarily been theoretical; it carries the probability work in the item stockage model, published in 1975, to a more general level. The approach assumes poisson requisition frequencies (generally a good assumption for arrival processes). Successful approach to this part of the problem required review of requisition size distribution estimators. The review led to reevaluation of the variance to mean square requisition size ratio on the basis of a DISC sample. Most importantly, however, a long-term technological replacement process for DLA items, which occurs at a varying rate for each item, has been assumed. The process is shown on Chart 3. Note that statistical fluctuations are permitted.

Repurchase costs have been formulated as fixed administrative charges plus the acquisition price of the units (see Chart 4). The administrative charge has different values for procurements in excess of $10,000. For low dollar procurements the fixed charge avoids the difficulties of a procurement cost rate. Since the repurchase cost is a future cost, it is discounted, but the inflated price of repurchase stock is not used because the discount factor of 10% is already net of inflation. Holding costs are considered to be only storage costs, at the cost rate of 1%, and since storage costs are a stream of future O&M expenditures, they are also discounted to present value.

The cost model thus weighs the expected cost of retention, which is the probability-weighted time stream of holding costs, against the expected cost of disposal, which is the probability-weighted repurchase cost. Thus, the model is an expected cost-binary decision problem (the two decisions being "dispose" versus "retain") where the minimum expected cost decision is chosen. The model is illustrated on Chart 5.

P_1 represents the probability that the demand occurs in the first year, P_2 the second year, etc. R is the repurchase cost and F is the discount factor applicable to the given year. hV is the holding cost. The cost outcomes of the retention decision are shown in parentheses. The expected cost of both the retention and disposal decisions were calculated for a variety of different obsolescence periods and annual demand values. Analysis of the solutions led to the following conclusions (see Chart 6).

For obsolescence periods in the range of 7-15 years, which are basically consistent with today's measured obsolescence rates, the

CHART 3

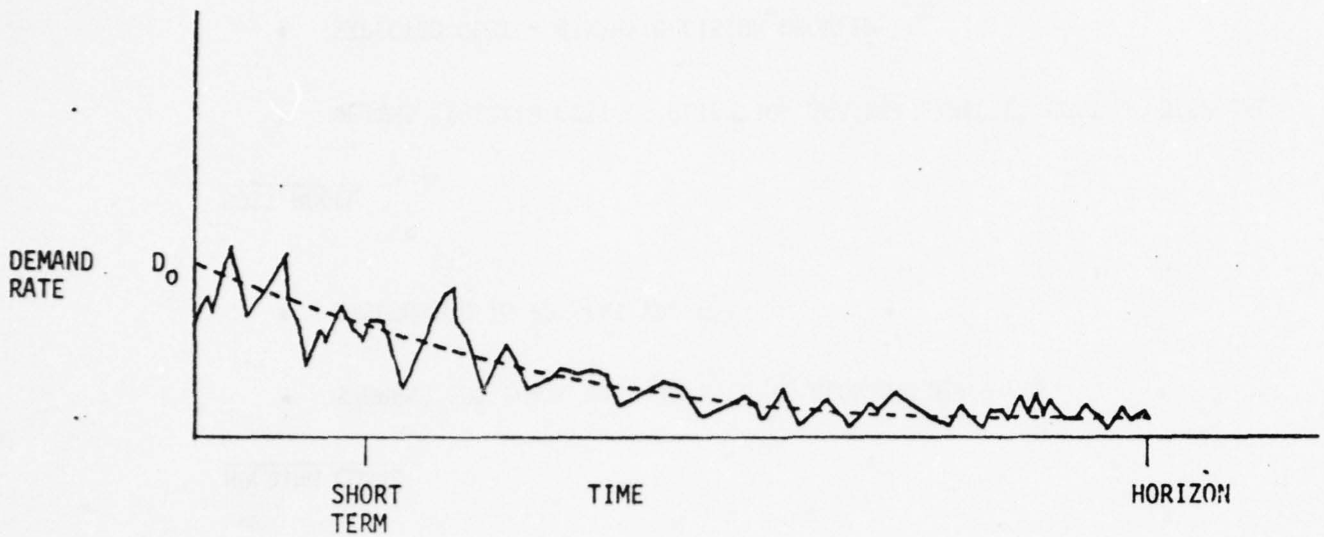


Figure 1. Statistical Variations in the Demand Rate, Decaying Process Mean and Variance

CHART 4

REPURCHASE COSTS

- FIXED CHARGE PLUS CURRENT ACQUISITION COST OF UNITS (INVESTMENT RATE OF 10% IS NET OF INFLATION)
- DISCOUNTED TO PRESENT VALUE

HOLDING COSTS

- STORAGE COST RATE (1%) APPLIED TO ACQUISITION VALUE
- DISCOUNTED TO PRESENT VALUE

COST MODEL

- WEIGHS EXPECTED COST OF RETENTION AGAINST EXPECTED COST OF DISPOSAL
- EXPECTED COST - BINARY DECISION PROBLEM

CHART 5

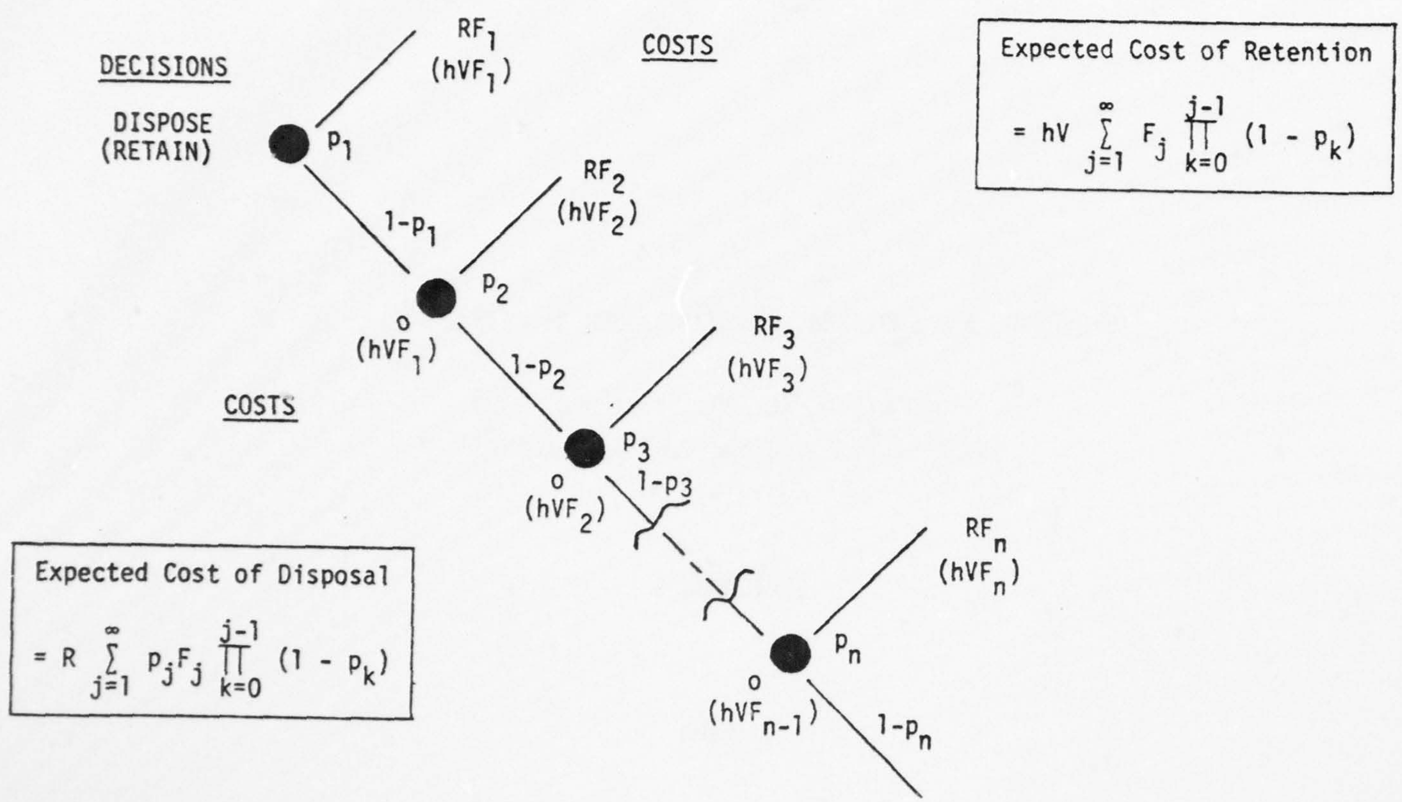


Figure 2. Dispose/Retain Decision Tree

CHART 6

CONCLUSIONS

- FOR OBSOLESCENCE PERIODS OF 7-15 YEARS
  ERL = 3-8 YEARS FOR ADV $<$ \$10,000

- RESULTS LARGELY CONFIRM PREVIOUS DLA-LO ANALYSIS

economic retention limit ranged from 3 to 8 years stock at the current demand rate for all annual demand values less than $10,000. Commodities with high obsolescence rates, such as electronics, would have an ERL at the lower value of the range, and those commodities with lower obsolescence rates would have ERLs at the higher end of the range.

These results largely confirm previous OR&EA analysis - apparently there are a number of routes to the same conclusion. The report on this work will be issued this summer, and the Directorate of Supply Operations may then recommend use of different ERLs, within the cited range, for each DLA commodity.

REVIEW OF NO DEMAND ITEMS

(Captain Denis F. Deveaux)

1. The purpose of this paper is to present new data which supports retaining excess inventories in the electronics commodity.

2. Data of several types were collected. Data from the fractionation tapes was saved for the period 1 April 1975 to 31 March 1976 and again for the period 1 April 1976 to 31 March 1977. Tapes for each period contained the demand characteristics for all items in the electronics inventory. Additionally, data was collected on individual items identified as having been in the DoD system at least nine years and had been experiencing low demands or no demands prior to CY 1977 and were now becoming active again.

3. Frequency distributions were developed from the procurement history data on the latter set of information collected in 2 above. Results strongly indicate a bathtub curve effect for electronics. This is graphically illustrated by the charts of reference 1 showing the number of procurements versus year in the system and number of units procured versus year in the system for 22 items in nine different classes. Additional data of this form is being collected and a sample of several hundred items will be used to verify the initial sample characteristics. It should be noted that 13 of the 22 items sampled experienced lapses in procurement action of from 6 to 10 years. Several items were found to have been in the system five to six years before the first procurement was made. The characteristics exhibited by the sample are exactly what those familiar with the operating characteristics of electronic parts would expect, i.e., that there is a short, initial burn-in period when failures known as "infant mortalities" occur, followed by a long period of "constant failure rate" in which there are few or no failures. This is followed by another period of increased failures where breakdown of parts occurs due to long exposure to environmental forces and stresses such as heat, humidity, power fluctuations, and circuit loading. As long as the end item application remains in the DoD system (and some end items predate World War II), this phenomenon can be expected to occur for many items in the electronics inventory.

4. The economics of retaining items in the inventory until it is fairly certain no user requirement exists should be self-evident. DoD has large tracts of strategically located real estate at which depots can be located using existing buildings and facilities. Costs of storage of inactive items is negligible for DoD because existing facilities can be used, there are no added costs of insurance and taxes as in industry, automated systems have eliminated the need for annual inventories, and no extra lights, heat, maintenance or warehousemen are needed to maintain these inventories. It cannot be shown that disposing of excess stock (electronics) will reduce any of the out-of-pocket costs. In fact, disposal will cost the government $3.33 per NSN with no hope of recovering any part of the cost of the item through return on disposal since DPDS operations are financed by these returns (1.26% for electronics). In addition, items previously sent to disposal have had to be recouped or rebought at a later date. Premiums to repurchase such items are often as much as 10 times the original cost and higher. An example is shown in reference 1.

5. The data collected from the fractionation tapes was used to obtain breakouts of items not having demand during the period 1 April 1975 to 31 March 1976 and before, that experienced demands during the period 1 April 1976 to 31 March 1977. It was determined that out of 573,006 items in the sample, 282,996 had not had demands before and/or during the period 1 April 1975 to 31 March 1976. Of these 282,996 items, 59,741 items or 21% became active during the period 1 April 1976 to 31 March 1977, experiencing some $9.078 million in demands. A more detailed breakout of these items by the number of years without demand prior to experiencing demand was inconclusive because many of these items had never had a demand since coming under the management of DESC. More detailed breakouts are being programmed using the management data to try to establish the length of period without demand for various items before experiencing demand. Data should be available by mid August 1977.

6. Preliminary results of our analysis indicate the following:

a. There is evidence that the bathtub effect exists for the electronics commodity.

b. Arbitrary disposal of items can be extremely costly to the government.

c. Many electronic items become active after experiencing long periods without demand.

d. There is no logical way to determine which items are not needed, regardless of how long they have been inactive, without the aid of the users.

e. Any additional costs of holding excess inventories (electronics) in DoD can be considered as negligible since no real out-of-pocket costs can be identified with these items that would constitute savings to the government if they were removed.

REFERENCES

1. DESC-LPO Briefing, subject: Review of No Demand Items (Enclosure).

REVIEW OF NO DEMAND ITEMS

PRESENTED BY

OPERATIONS RESEARCH AND ECONOMIC ANALYSIS GROUP

DESC-LPO

OUTLINE

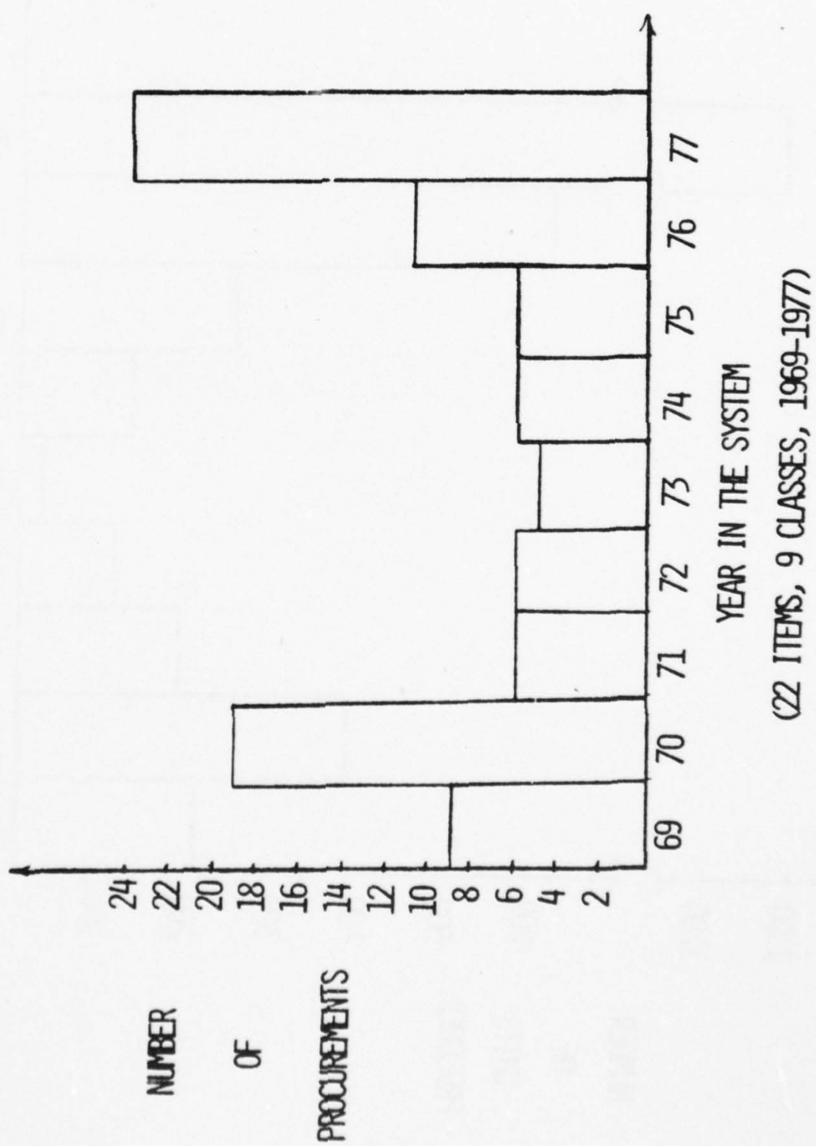
- PURPOSE
- KEY POINTS
- BATHTUB CURVE IS REAL FOR ELECTRONICS
- EXAMPLES
- BREAKOUT OF NO DEMAND ITEMS
- SOME ADDITIONAL STATISTICS
- CONDITIONAL PROBABILITY OF NO DEMAND
- CONCLUSIONS
- ACTION RECOMMENDED

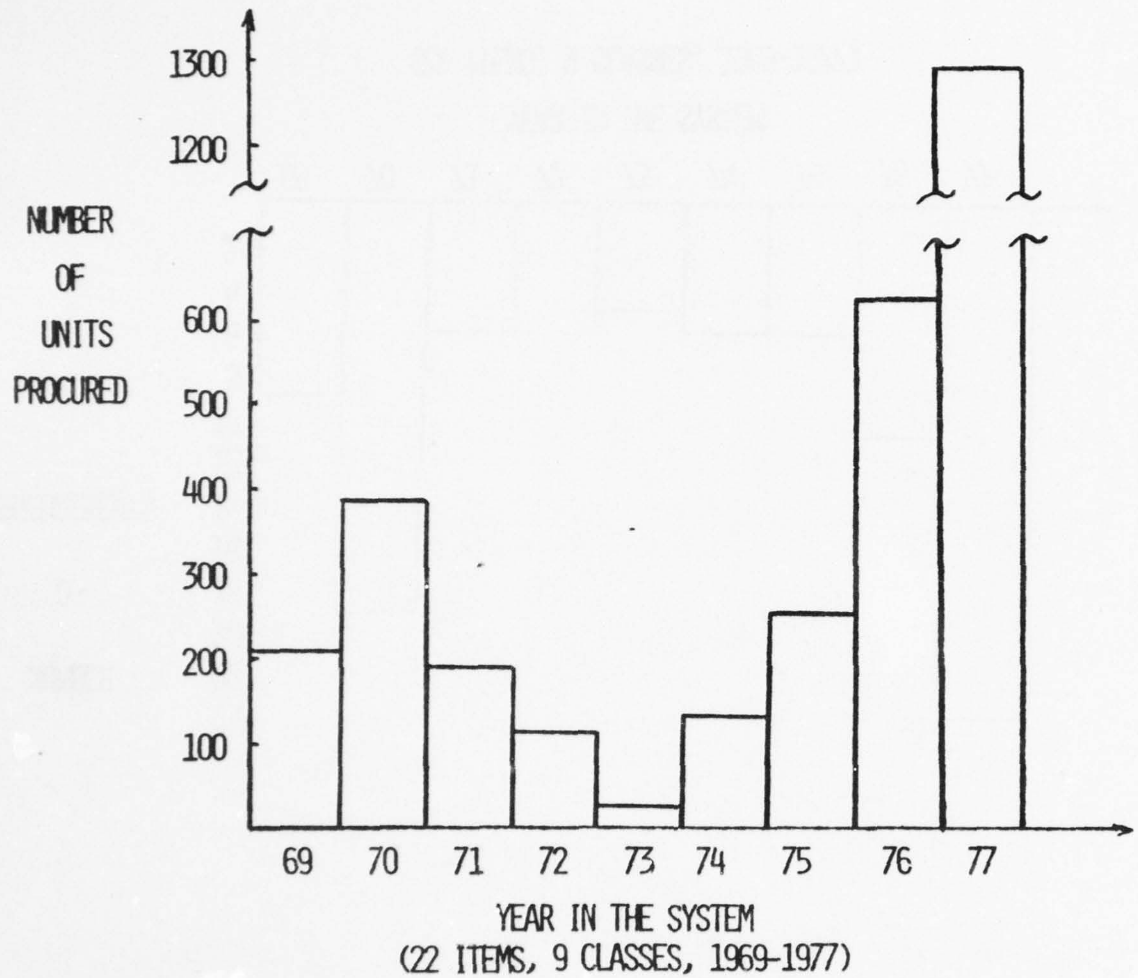
PURPOSE

- TO PRESENT NEW DATA WHICH SUPPORTS RETAINING EXCESS INVENTORIES IN ELECTRONICS BEYOND 6 YEARS.

KEY POINTS

- THE BATHTUB CURVE IS REAL FOR ELECTRONICS
- A FEW ITEMS IDENTIFIED BY PROJECT PURGE ARE ALREADY EXPERIENCING DEMAND
- 59,741 NO DEMAND ITEMS AS OF 31 MAR 76 EXPERIENCED DEMANDS IN APR 76 TO MAR 77
- OF THE ABOVE, 15,405 ITEMS
  HAD BEEN 10 OR MORE YEARS WITHOUT DEMAND OR
  HAD NEVER HAD A DEMAND


NUMBER
OF
PROCUREMENTS
24
22
20
18
16
14
12
10
8
6
4
2
69
70
71
72
73
74
75
76
77
YEAR IN THE SYSTEM
(22 ITEMS, 9 CLASSES, 1969-1977)


NUMBER
OF
UNITS
PROCURED
1300
1200
600
500
400
300
200
100
69
70
71
72
73
74
75
76
77
YEAR IN THE SYSTEM
(22 ITEMS, 9 CLASSES, 1969-1977)

EXAMPLES

NSN	NUMBER PROCURED	YEAR PROCURED	YEARS BETWEEN PROCUREMENTS
5910-00-941-8078	11	1966	
	41	1967	
	15	1977	9.8
5930-00-941-0388	33	1969	
	120	1969	
	184	1977	8.0
	262	1977	
5935-00-198-3908	11	1969	
	3	1977	8.0
	27	1977	
	8	1977	
5930-00-410-1390	2	1975	6.0 BEFORE
	2	1976	FIRST PROCUREMENT
	2	1977	
	24	1977	

EXAMPLES (CONTINUED)

ITEMS IDENTIFIED BY PROJECT PURGE
FOR DISPOSAL NOW EXPERIENCING DEMANDS

NSN	DATE LAST PURCHASED	LAST UNIT PRICE	CURRENT UNIT PRICE
5950-00-997-5200 *	1967	$11.09	$50-100
5950-00-412-0877	1970	$ 4.50	$ 7.38

* COST TO REPURCHASE 1 UNIT:

3.33	DISPOSAL
76.62	FIXED PROC.
50.00	MIN. UNIT PRICE
129.95	MIN. COST TO REPURCHASE 1 UNIT + TC
50.00	ADD. COST IF $100/UNIT
179.95	TOTAL POSSIBLE COST OF 1 UNIT + TC

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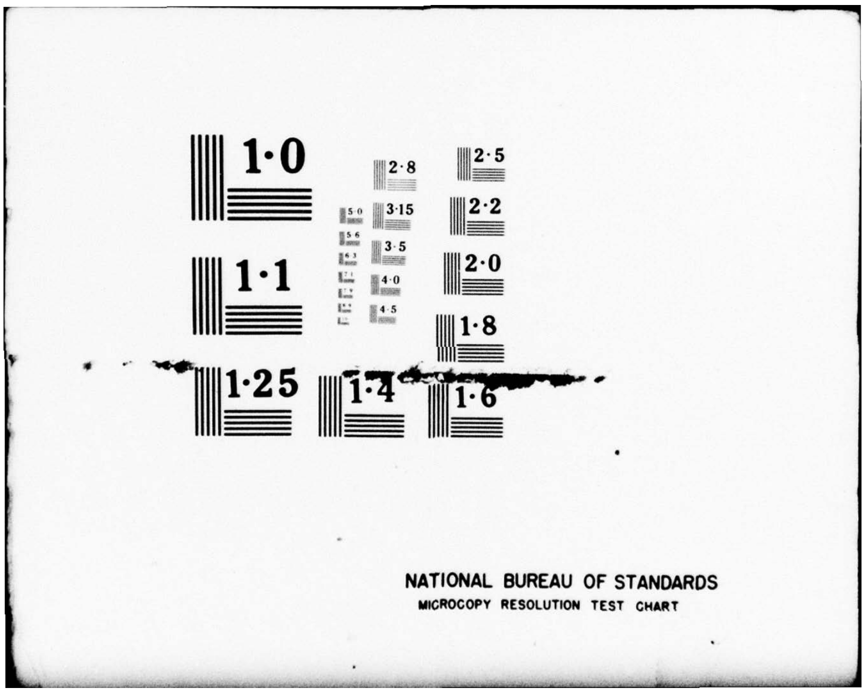
1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

BREAKOUT

OF

NO DEMAND ITEMS

ITEMS WITH NO DEMAND
FROM 1 APR 75 - 31 MAR 76 *
HAVING DEMANDS
1 APR 76 - 31 MAR 77

CHARACTERISTIC	SSCI	SSCA	ALL OTHER	TOTAL
77 DEMAND $	1.757M	4.028M	3.293M	9.078M
77 DEMAND FREQ	21,675	50,800	44,453	116,928
NO. OF ITEMS	2,991	32,783	23,967	59,741

* INCLUDES ITEMS HAVING NO DEMAND 1, 2, ..., 10, ..., N YEARS PRIOR TO 1 APR 75 AND 1 APR 75 - 31 MAR 76

BREAKOUT BY YEARS WITHOUT DEMAND
PRIOR TO 1 APR 76

77 DEMAND DOLLARS	77 DEMAND FREQUENCY	NUMBER OF ITEMS	YEARS WITHOUT DEMAND
3.162M	40,715	20,956	1
.696M	10,902	6,577	2
.620M	8,919	5,963	3
.268M	3,409	2,301	4
.074M	1,343	1,024	5
•	•	•	•
•	•	•	•
•	•	•	•
2.496M	31,665	15,405	10 *

* 10 YEARS OR MORE, OR NEVER HAD DEMAND BEFORE 1 APR 76

CONDITIONAL PROBABILITY
OF
NO DEMAND

(PROBABILITY OF NO DEMAND IN ONE YEAR GIVEN
THAT DEMAND OCCURED IN THE PREVIOUS YEAR)

DEMAND FREQUENCY	PROBABILITY
1	.505
2	.327
3	.219
4	.144
5	.094
6	.069
7	.048
8	.031
9	.023
10	.020
11	.013
12	.011
13 OR MORE	.002

CONCLUSIONS

- EVIDENCE THAT BATHTUB EFFECT EXISTS IN ELECTRONICS COMMODITY
- DISPOSAL CAN BE COSTLY
  - $3.33/NSN
  - HIGH REPURCHASING COSTS
  - NO SOURCE
- MANY ELECTRONIC ITEMS BECOME ACTIVE AFTER LONG PERIODS WITHOUT DEMAND
- NO WAY TO DETERMINE STOCK NOT NEEDED WITHOUT THE AID OF CUSTOMERS
- DOESN'T COST ANYTHING TO HOLD STOCK UNTIL YOU FIND OUT

ADDITIONAL STATISTICS

- 23% OF ITEMS ACTIVE IN 1976 NOT ACTIVE IN 1977
- 21% OF ITEMS NOT ACTIVE IN 1976 WERE ACTIVE IN 1977
- 50% OF ELECTRONICS ITEMS ACTIVE IN 1977

ACTION RECOMMENDED

- RETHINK DISPOSAL PHILOSOPHY FOR ELECTRONICS
- DISCONTINUE PROJECT PURGE FOR ELECTRONICS UNTIL MORE DETAILED BREAKOUTS OF DATA AVAILABLE

UNIFORM SAMMS INVENTORY MANAGEMENT SIMULATION GROUP MEETING

by
Dennis L. Zimmerman

I. INTRODUCTION

As part of the OR/EA Symposium Group Sessions, a meeting was held to discuss the Uniform SAMMS Inventory Management Simulation (USIMS). The discussion centered around USIMS applications, problems, and proposals for improvements. The participants in the group meeting were OR analysts from DLA-LO and the DSCs, with the exception of DESC and DGSC. This report summarizes the discussion at the USIMS group meeting.

II. DISCUSSION

A. Applications. Little application of USIMS at the DSCs was reported by the participants. Only DPSC is actively using USIMS. There appear to be three reasons for the low reported usage.

1. At the present time, many of the OR projects being done in DLA are not USIMS applications.

2. USIMS does model SAMMS, but there is some question as to how well USIMS models actual inventory management at the individual DSCs.

3. Although USIMS has been in existence for some time, some DSC personnel are still involved in the process of validation and familiarization.

B. Problems. Only one specific problem was discussed at the meeting. It involved strange results at DPSC from USIMS runs testing the DoD variable safety level. Some of the problems were identified as user errors.

General problems cited were the selling of USIMS to management, the applicability of USIMS in view of the unique application of SMCC codes at each DSC, and the lack of a USIMS Made Simple Handbook for analysts and management alike.

C. Proposals for Improvements. The proposals for improvements from the last USIMS meeting, which was held in October 1975, were reviewed along with the action(s) taken on each proposal. The proposals and actions are listed in Table 1.

No new specific proposals to change USIMS were made. General proposals were that guidance on USIMS application and additional USIMS documentation be provided to the DSCs.

Table 1. 1975 Proposals for Improvements

Proposals	Action(s)
1. DCSC	
a. Determine the cause of the high initial surge in simulated commitments and modify USIMS accordingly.	a. A possible cause of the surge may be the fact that USIMS data does not include recommended buys in the item assets. To offset this, an option has been provided in FRONT to create due-ins for items below the reorder point.
b. Add a report which will match the mean average deviation (MAD) of USIMS to the MAD of SAMMS to aid in knobbing demands.	b. MAD report has been added to USIMS.
c. Construct a program to allow knobbing outside of simulation.	c. No action taken. This proposal has merit and such a program will be constructed.
d. Revise variable safety level (VSLR) usage or add a new adjustment variable for safety level.	d. No action taken.
2. DESC	
a. Include in item sample extraction:	a. No action taken.
(1) Nonstocked items.	
(2) Items with zero numeric stockage objective (NSO) quantity fields.	
(3) SMCC codes.	
b. Correct error in FRONT program option dealing with conversion of VIP items, non-VIP items.	b. Error has been corrected.
c. Include individual item demand history in the demand generator to give a more accurate simulation of actual demands.	c. This idea will be included in the construction of separate demand generator program. (See 1c.)

Proposals	Action(s)
d. Allow options to modify incoming data, such as quarterly forecasted demand (QFD) so that USIMS will more accurately model actual levels.	d. Additional options to be included in FRONT are being studied.
e. Change monthly reports to quarterly reports to reduce running time and free machine capacity to expand other USIMS operations (e.g., number of years of simulation).	e. Proposal not accepted.
3. DGSC	
a. Include END option in item data read into the simulation.	a. Option has been included.
b. Allow USIMS output by categories other than value of annual demand.	b. No action taken.
c. Furnish change cards with new USIMS versions.	c. Because of the unique ADP system at each DSC, change cards from DLA-LO would be of no use to some DSCs. However, if requested by a DSC, they will be furnished.
d. Incorporate SMCC codes.	d. Because of the different applications of SMCC codes at the DSCs, this proposal could not be adopted.
4. DISC	
a. Make a study of requisitions to determine if a better demand generator can be devised.	a. DLA requisitions are being studied and a change to USIMS is being made in order to improve USIMS demand replication.
b. Allow "knobbing" outside the simulator.	b. See 1c.
c. Provide detailed documentation on coding to aid in understanding the model.	c. No action taken.
d. Strengthen the item data validation routine.	d. This problem is correcting itself as SAMMS files are being cleaned up.

Proposals	Action(s)
e. Change USIMS to compute initial levels in STARTX in the same manner as MIAC. Should reduce the initial commitments surge.	e. See 1a.
5. DPSC - No proposals, just went on SAMMS.	5. USIMS activity is now taking place at DPSC.
6. DLA-LO	
a. Change requirement to submit parameter cards and USIMS tape from quarterly to not less than annually or whenever a DSC makes a change. DSCs agreed and also asked that the 20-day requirement for submitting cards and tape be dropped.	a. Changed as follows: (1) A magnetic tape containing the Simulation Data Extraction Program (SRH 120) and a copy of the USIMS COBOL reports are to be sent to DLA-LO within 45 days after the end of each quarter. (2) A copy of the parameter cards used to run the Front-End and simulation programs are to be furnished to DLA-LO within 45 days after the end of the first and third quarters of each fiscal year.

III. CONCLUSIONS

A. Low Usage. The low usage of USIMS could be improved by taking the following actions:

1. Simplify the USIMS procedures to permit usage by management.

2. Provide guidance on how management can use USIMS and on what management can expect from USIMS.

3. Resolve the conflict with SMCC codes by either:

a. Permitting USIMS to be modified, DSC by DSC, to accommodate SMCC; or,

b. Standardizing the application of SMCC codes throughout DLA (the less plausible of the two alternatives at this time).

B. Improvements. USIMS could be upgraded by a renewed effort on past proposals. In particular, the following proposals should be worked on:

1. Construction of a demand generator outside of the simulator.

2. Expansion of the USIMS data base.

C. Recommendations. Besides the improvements mentioned above, the following documents should be prepared:

1. A USIMS Made Simple Handbook.

2. A Paper on Simulation - When, How, and What to Expect.

3. Detailed Documentation on the USIMS Programs.

COMMERCIAL ITEM SUPPORT PROGRAM

by
John W. Melone

The purpose of this presentation is to inform the DLA operations research community of the objectives of the Commercial Item Support Program (CISP) and the role of the Operations Research and Economic Analysis Office in support of this project. In general, the OR&EA Office has committed itself to the development of cost data and cost models for the Commercial Item Task Group (CITG) in implementation of this program.

To provide some brief background on this program, in May of 1976 the Office of Federal Procurement Policy (OFPP) in the Office of Management and Budget (OMB) issued a policy statement calling for government agencies to utilize commercial, rather than government, distribution systems (see Chart 1). Subsequently, in August of 1976 and January of 1977 the GAO issued two reports in this subject area. These reports stated that the DLA managed and stocked many low-use, commercially available items which could be supplied through local purchase, thereby avoiding unnecessary costs, and that lack of consideration by DLA of the full landed cost of supply support for these items resulted in erroneous cost-justification for stockage. Full landed cost means the price paid for the item plus its allocated share of the cost to support the system used to acquire and deliver it. It is thus an average cost concept.

By memorandum of 18 Jan 1977 ASD(MRA&L) restated the OFPP policy, but added two major points (see Chart 2). First, the memo required that DoD activities consider total costs (that is, landed costs) in determining the most advantageous method of acquiring and distributing an item. The total cost models which have been developed by the OR&EA Office to carry out this directive are discussed below. In addition, the memo added the requirement to consider military readiness in determining the most advantageous method of support.

The ASD memo also stated that the CISP will involve four major steps.

First, items will be selected in manageable increments; the memo, as written, requires detailed "testing" of 10 selected DLA-managed items. This testing envisions procurement of each item by various methods and "costing" each method at all echelons. This approach appears questionable since a test of 10 items will accomplish little toward determining the disposition of 1.6 million SSC-1, SSC-3, SSC-7 and SSC-A items.

USE OF THE
COMMERCIAL
DISTRIBUTION SYSTEM

CHART 1

OFPP POLICY - MAY 1976

"THE GOVERNMENT WILL PURCHASE COMMERCIAL, OFF-THE-SHELF PRODUCTS WHEN SUCH PRODUCTS WILL ADEQUATELY SERVE THE GOVERNMENT'S REQUIREMENTS, PROVIDED SUCH PRODUCTS HAVE AN ESTABLISHED COMMERCIAL MARKET ACCEPTABILITY. THE GOVERNMENT WILL UTILIZE COMMERCIAL DISTRIBUTION CHANNELS IN SUPPLYING COMMERCIAL PRODUCTS TO ITS USERS."

THE COMMERCIAL ITEM SUPPORT PROGRAM (CISP)

CHART 2

<u>ASD(I&L) -- 18 JAN 77</u>

- RESTATES OFPP POLICY
  - ADDS TOTAL COST CONSIDERATION
  - ADDS MILITARY READINESS CONSIDERATION
- CISP WILL CONSIST OF FOLLOWING STEPS
  - ITEM SELECTION (IN INCREMENTS)
  - REVIEW OF COMMERCIAL ITEM AVAILABILITY TO DETERMINE CENTRAL OR LOCAL MANAGEMENT
  - DECISION ON USE OF DoD, COMMERCIAL, OR <u>COMBINATION</u> DISTRIBUTION CHANNELS
  - SELECTION OF MOST ADVANTAGEOUS PROCUREMENT
- DLA TO DEVELOP DETAILED CISP PLAN FOR MIL SVC COMMENTS (AS TO IMPACT) AND ASD APPROVAL

The next step in the CISP process requires a review of item commercial availability to determine the potentials for local purchase. Having made that determination, a decision would then be made on the use of DoD or commercial distribution channels, or a combination approach. The last step is the selection of the best method of procurement.

In developing its approach to the CISP, the CITG adopted four basic objectives (see Chart 3). The first objective is to achieve the maximum use of commercial distribution channels, consistent with cost and readiness considerations.

The second objective is to reduce the number of commercial items which we stock and possibly reduce the quantity in store.

The third objective is to achieve economy in product acquisition and distribution through the application of total (landed) costs.

The last objective is to mount a significant effort in commercial distribution without creating degradation of responsiveness and readiness.

Initially, there are categories of items which in the opinion of the CITG should be excluded from consideration under the CISP (see Chart 4). First, Military or Federal Specification items will not be considered until they have been subjected to the parallel Commercial Commodity Acquisition Program (CCAP). Additionally, items directly tied to readiness such as Mobilization Reserves, weapons systems items, and valid "insurance" items also will be excluded. Lastly, those items which require extraordinary quality assurance efforts, or are identified as diminishing source items will be excluded.

At this time there are some serious concerns which people in the Headquarters and the field have voiced (see Chart 5). Probably the most serious concern is the extent to which extensive use of the commercial distribution channels will affect our ability to meet high priority and NORS/ANORS demands within UMMIPS time frames. Also, when items are decentralized for local purchase, we lose sight of the demand and, consequently, lose sight of the item itself. We have no idea whether or not the item should remain in the catalog. Certainly, an even more difficult taks is measuring the effectiveness of a system which would have stocks supplied by a variety of acquisition and distribution methods.

Another problem is the determination of commercial availability. It is difficult to find two consistent definitions of this term. Some define it on a geographical availability basis, and others on a response-time basis.

Finally, all decisions on the best distribution method for a commercial item eventually will have to face the problem of existing stocks on hand - particularly those many items in long supply.

THE

COMMERCIAL ITEM

SUPPORT PROGRAM

(CISP)

CHART 3

BASIC OBJECTIVES

- TO ACHIEVE MAXIMUM UTILIZATION OF COMMERCIAL DISTRIBUTION CHANNELS
- TO REDUCE THE NUMBER OF COMMERCIAL ITEMS BEING STOCKED AND HANDLED IN DoD DISTRIBUTION FACILITIES
- TO ACHIEVE ECONOMY IN PRODUCT ACQUISITION AND OPERATING COSTS
- TO ACCOMPLISH THE ABOVE WITHOUT DEGRADATION OF MILITARY READINESS

CHART 4

THE

COMMERCIAL ITEM

SUPPORT PROGRAM

(CISP)

<u>ITEMS INITIALLY EXCLUDED FROM CISP</u>

- MIL SPEC/DRAWING ITEMS
- MOBILIZATION RESERVE ITEMS
- INSURANCE/WEAPONS SYSTEM ITEMS
- PRODUCT QUALITY ASSURANCE ITEMS
- DIMINISHING SOURCE ITEMS

THE

COMMERCIAL ITEM

SUPPORT PROGRAM

(CISP)

CHART 5

PRINCIPAL CONCERNS WITH CISP

- QUESTIONABLE RESPONSIVENESS TO HI-PRI DEMANDS
- LOSS OF DEMAND HISTORY (ITEM VISIBILITY)
- DIFFICULTY IN MEASURING EFFECTIVENESS
- DETERMINATION OF COMMERCIAL AVAILABILITY
- UTILIZATION OF ON HAND STOCKS

Another problem the Task Group has faced in approaching this program is the concept of total costs (see Chart 6). The application of total costs in determining the method of acquiring and distributing an item has been the subject of considerable discussion over the past years. In the OFPP approach, this is not an issue. The feeling there is that the use of the commercial system is the most cost effective method and no formula is needed to prove it. ASD(MRA&L), however, has required total cost considerations to be an integral part of this program. This is also DLA policy. As mentioned previously, we have been criticized by the GAO recently for not using total costs in our item decisions.

It is important to appreciate the magnitude of the effort in this total cost approach. All DLA O&M costs, by organization, must be reviewed and that portion of the cost which is attributable to the management of DLA assigned items of supply must be included in the total cost. This part of the effort has been completed and is being reviewed by the Task Group. Then, depending on the type of cost model, we have to deduct from the total cost those costs which are variable costs, so that we are left with the annual management charges to be prorated to each item. The following three cost models have been developed (see Chart 7).

In conclusion, the status of this effort is that the full cost factors developed by the OR&EA Office are being reviewed by the Task Group. Also, the details on the use of the cost models are in draft. Both the cost data and the cost models will be reviewed by the DLA staff prior to transmittal to ASD(MRA&L) for review and approval.

THE

COMMERCIAL ITEM

SUPPORT PROGRAM

(CISP)

CHART 6

CISP ANALYSES ON "TOTAL COST" BASIS

- NOT REQUIRED (OR EVEN ENCOURAGED) BY OFPP
- REQUIRED BY ASD(I&L)
- RECOMMENDED BY GAO
- PROMISED TO GAO
- DIFFICULT TO DEVELOP FULLY

CHART 7

CISP TOTAL SUPPORT COST (TSC) MODELS

SSC1: $TSC1 = K + P_1D + AD/Q + HP_1(Q/2 + S) + JF + TF$

SSC2: $TSC2 = (1 + R)\ P_2D$

SSC3: $TSC3 = L + BF + P_3D$

A,B = PROCUREMENT COSTS

Q = BUY QUANTITY

D = FORECASTED ANNUAL DEMAND

F = FORECASTED ANNUAL FREQUENCY

P_i = PRICE/UNIT FOR SSC-i

S = SAFETY LEVEL

K,L = MANAGEMENT CHARGES

H = HOLDING COST RATE

R = SSC-2 OVERHEAD COST RATE

J,T = ISSUE, TRANSPORTATION COSTS/LI

DESC PRICE BREAK STUDY

(Captain Denis F. Deveaux)

1. References:

a. OM IOM, 23 June 1976, subject: Price Breaks.

b. LS IOM, 10 September 1974, subject: Minimum Buy and Price Break Policy.

c. Austin, L. M. and R. E. Carlburg. "Use of EOQ Technique Obtains Price Discounts," Defense Management Journal, July 1975.

PROBLEM

2. To develop methods that can be used to evaluate quantity discount prices where savings to the Government warrant the extra investment in increased PR quantity.

FACTORS BEARING ON THE PROBLEM

3. Facts.

a. Current operating policy guidelines which apply to price break situations provide no way of establishing when savings in unit price warrant added investment.

b. Current operating policy guidelines apply arbitrary dollar value limits to PR quantity increases which DESC-P may not exceed without DESC-O coordination.

c. Except in obvious cases, the most economical buy for the government is not evident under current operating policy guidelines, and choosing the best buy is often due to chance.

d. In a sample of awards furnished by PA, it was found that DESC chose what should have been the optimal buy, as calculated by a price break formula, only about 31 percent of the time where price breaks were offered.

e. In this same sample, it was found that useful price break information was available on only 45 percent of the awards over $10,000 and only 24 percent of the awards under $10,000.

f. Price discount techniques field tested by the Air Force have proven both valid and workable, resulting in price discounts which averaged 4.5 percent on tested solicitations (reference 1.c.).

DISCUSSION

4. Current operational policy guidelines regarding price breaks as outlined in reference 1.b. provide no specific formula for evaluating price breaks to determine when savings in unit cost warrant the extra investment in increased PR quantity. OM has requested assistance in evaluating quantity discounts as per reference 1.a.

5. DESC-LPO has developed a simplified procedure for establishing the most economical buy based upon computation of the average annual cost to the Government of maintaining the item. This procedure is well documented in the literature and is the accepted method for determining the optimal order quantity when considering quantity discounts.

6. DESC-LPO selected a sample of 134 award contracts and POs from PA's contract files for this study. The sample was drawn to be a proportion of the contracts and purchase orders awarded during the FY-7T quarter and reflects what actions were taken in awarding buys on items for which a schedule of price breaks was available. The total savings possible, based on the minimum annual cost formula developed in Enclosure 1, Appendix A, was $39,569.42 for the 42 items which had price breaks offered.

CONCLUSIONS

7. Implementation of an aggressive quantity discount program should increase stock availability and will provide more stock for less money in the long run.

8. Projections inferred from the sample over awards made in FY-7T from PERS data indicate potential savings of about $15,610,844.96 annually using the price break formula.

9. The low percentage of awards which had useful price breaks offered in the sample selected indicates that perhaps DESC is not as aggressive as it should be in soliciting price breaks. The potential to significantly increase savings above the amount inferred by the sample lies in improving procedures for soliciting and utilizing quantity discounts.

10. It is to be noted that if useful price breaks could be applied to more contracts and PO's, annual savings could be substantially higher than the current sample indicates. Table 10.1 shows the potential annual savings that might occur if useful price break information were available on from 30 to 100% of all contracts and purchase orders.

TABLE 10.1
POTENTIAL ANNUAL SAVINGS
OBTAINED FROM USEFUL QUANTITY PRICE BREAKS

Percentage of Contracts/POs With Useful Price Break Information	Savings for Awards < $10,000	Savings for Awards > $10,000	Total Savings
100%	$30,059,343	$18,178,612	$48,237,955
90%	$27,053,409	$16,141,159	$43,194,568
80%	$24,047,474	$14,542,889	$38,590,363
70%	$21,041,540	$12,725,028	$33,766,568
60%	$18,035,606	$10,907,167	$28,942,773
50%	$15,029,671	$ 9,089,306	$24,118,977
40%	$12,023,737	$ 7,271,444	$19,295,181
30%	$ 9,017,803	$ 5,453,583	$14,471,386
Current Rate (22%, 45%)	$ 7,347,839	$ 8,263,005	$15,610,844

From this data, annual savings of between $15 million and $30 million would appear to be a realistic DESC goal if an aggressive program for soliciting and utilizing quantity discounts is adopted.

11. A study conducted by the Air Force to assess the impact of a similar technique to reduce AFLC costs using price discounts proved both workable and cost effective (reference 1.c.). Additionally, the study resulted in

improved procedures for soliciting and utilizing quantity discounts, improved methods of predicting demand and identifying and handling essential items, improved procedures for handling infrequently demanded items, and improved cross-functional communications. It is reasonable to assume that DESC and DLA might also receive such benefits as by-products of continued study and a vigorously applied quantity discount program.

12. The procedure outlined in Technical Report 77-2 has a wide range of application and could result in substantial savings to the government if applied DLA wide.

13. It should be noted that this proposal is (a) not a new system, (b) not a new concept, and (c) not proposing something we aren't already doing. What this proposal provides DESC is a better way of doing what we already do.

OTHER CONSIDERATIONS

14. The study indicates an expected 17.43% increase in investment on awards less than or equal to $10,000 for each price break taken advantage of. The expected rate of increase for awards greater than $10,000 is 12.88%. Thus, if DESC typically invests $43.7 million per quarter on stock replenishment items, and the DESC goal is to solicit useful price breaks on 50% of all contracts and PO's, then DESC will have to plan for an initial increase in stock fund expenditures of about $3.7 million for the first quarter in which the program is implemented. Added investment after the initial increase will tend to be reduced in later quarters, and, in the long run, annual investment should be approximately the same as before the program is started.

ACTION RECOMMENDED

15. Implement a pilot test program and set up procedures to:

a. Collect the necessary cost and award data to validate savings and workability of the program.

b. Estimate the manpower impact on the system.

c. Review Table 9 for any changes necessary to preclude generating too many D/Is because stock is above the SOR due to increased quantities resulting from buys where quantity discounts were obtained.

d. Limit the test program initially to items in the 5950 and 5985 classes for purposes of data collection and verification of savings and workability of the program.

e. Establish a standard solicitation form which calls for a full range of quantity discounts on items solicited.

f. Solicit price break information on as many stock replenishment items as possible.

16. Advise DLA of the program being implemented at DESC and furnish them with an official copy of Technical Report 77-2. Recommend implementation of test programs at other DSCs, if not already in use.

DESC

PRICE BREAK

STUDY

PREPARED
BY

OPERATIONS RESEARCH AND ECONOMIC ANALYSIS GROUP

DESC-LPO

OUTLINE

* PURPOSE
* KEY POINTS
* FACTS
* PRICE BREAKS NOT NEW
* POTENTIAL ANNUAL SAVINGS
* OTHER CONSIDERATIONS
* GROUND WORK COMPLETED
* SUMMARY
* ACTION RECOMMENDED

PURPOSE

DEVELOP METHODS TO EVALUATE QUANTITY DISCOUNTS

KEY POINTS

* MOST ECONOMICAL BUY NOT CURRENTLY EVIDENT
* PRICE BREAKS NOT NEW
* POTENTIAL ANNUAL SAVINGS EXCEEDS $15 MILLION
* OTHER CONSIDERATIONS
* GROUND WORK COMPLETED

FACTS

* CURRENT GUIDELINES
    * APPLY DOLLAR VALUE LIMITS TO PR QUANTITY INCREASES
    * PROVIDE NO WAY TO EVALUATE SAVINGS
    * LIMIT CHOICES MAINLY TO OBVIOUS CASES
* TEST SAMPLE SHOWS
    * PRICE BREAK INFORMATION FURNISHED ON
        * 45% OF AWARDS > $10,000
        * 24% OF AWARDS < $10,000
    * OPTIMAL BUY WAS CHOSEN ONLY 31% OF THE TIME

PRICE BREAKS NOT NEW

* METHOD DEVELOPED IS
  * NOT A NEW SYSTEM
  * NOT A NEW CONCEPT
  * NOT SOMETHING WE AREN'T ALREADY DOING
* IT'S A BETTER WAY OF DOING WHAT WE ALREADY DO

ANNUAL COST EQUATION

(SYSTEM)

$$K = \underset{\substack{\text{ANNUAL}\\\text{ORDER}\\\text{COST}}}{\frac{4 \times QFD \times A}{Q}} + \underset{\substack{\text{ANNUAL}\\\text{HOLDING}\\\text{COST}}}{H \times C \times \frac{Q}{2}} + \underset{\substack{\text{ANNUAL}\\\text{BACKORDER}\\\text{COST}}}{1.48 \times F \times \frac{PRQTY}{Q}} + \underset{\substack{\text{ANNUAL}\\\text{MATERIAL}\\\text{COST}}}{4 \times QFD \times C}$$

EXAMPLE

NSN = 5915-00-7590506

QFD = 7

F = 24

PRQTY = 30

Q	C	Q.C	A
30	$255	$ 7,650	$ 76.62
35	$245	$ 8,575	$ 76.62
50	$240	$12,000	$163.43

EXAMPLE (CONTINUED)

Q	C	ORDER COST	HOLDING COST	BACKORDER COST	MATERIAL COST	TOTAL COST
30*	255	71.51	956.25	35.52	7140	8203
35**	245	61.30	1071.87	30.45	6860	8023
50	240	91.52	1500.00	21.31	6720	8332

* QUANTITY AWARDED

** OPTIMUM BUY

POTENTIAL ANNUAL SAVINGS (MILLIONS)

% CONTRACTS/PO's W/PRICE BREAK INFO	SAVINGS AWARDS <$10,000	SAVINGS AWARDS >$10,000	TOTAL SYSTEM SAVINGS
CURRENT RATE 24% < $10,000 45% > $10,000	$ 7.3	$ 8.3	$15.6
30%, 45%	9.0	8.3	17.3
40%, 45%	12.0	8.3	20.3
50%	15.0	9.1	24.1
60%	18.0	10.9	28.9
70%	21.0	12.7	33.7

OTHER CONSIDERATIONS

* BUDGETARY LIMITATIONS
* INITIAL INCREASE IN OBLIGATIONS
    * CAN BE CALCULATED
    * WILL STABILIZE
    * TOTAL ANNUAL INVESTMENT APPROXIMATELY THE SAME
* POSSIBLE INCREASE IN D/I's
* TIMING IS IMPORTANT

GROUND WORK COMPLETED

* PILOT TEST PROGRAM DEVELOPED
  * 5950, 5985
  * ACCOUNTING PROCEDURES
  * SOLICITATION FORMS
  * IM WORKSHEET
  * MANPOWER STUDY
  * TABLE 9 REVIEW
  * VERIFICATION OF SAVINGS

SUMMARY

* MOST ECONOMICAL BUY NOT CURRENTLY EVIDENT
* METHOD DEVELOPED PROVIDES INFORMED DECISIONS
* ANNUAL SAVINGS IN EXCESS OF $15 MILLION EXPECTED
* OTHER CONSIDERATIONS
* GROUND WORK COMPLETED

ACTION RECOMMENDED

* IMPLEMENT THE PILOT TEST PROGRAM

* ADVISE DLA

OR/EA INTERFACES
by Laurence Kohler

After formal presentations, a discussion was held between Headquarters and Field Activity OR/EA analysts. The purpose was to find out whether, and how well, OR/EA is being used in DLA and how its use might be enhanced. The following actions reflect the topics discussed:

1. Review the organizational placement of OR/EA in the field and recommend changes, if necessary.

2. Revise DSAR 5100.3, Operations Research and Economic Analysis in DLA, to clarify the role of OR/EA personnel.

3. Provide Field Activities with a list of OR/EA courses available from Federal Agencies.

4. Develop an Index of OR/EA publications relating to depots.

5. Provide for the "Navy Logistics Quarterly" to be sent to OR/EA personnel in the field.

6. Develop means for HQ DLA to emphasize the importance of OR/EA and suggesting how OR/EA personnel should be used.

7. Send draft copies of current OR/EA studies to field personnel for comment.

8. Provide for an OR/EA Newsletter.

9. Provide guidance on submission of reports to central repository of logistics studies, DLSIE, Ft. Lee, Va.

10. Provide guidance for field OR/EA personnel on how to justify computer equipment or time.

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